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Food security effects of intensified dairying: Evidence from the Ethiopian highlands

Socio-economics and Policy Research

International Livestock Research Institute

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Executive summary

This study examines the food security and marketed surplus effects of intensified dairying in a peri-urban area of Addis Ababa, Ethiopia, where a market-oriented dairy production (MODP) system has been introduced for smallholders. The system involved the introduction of crossbred cows and the utilisation of complementary feed and management technologies for increased dairy production. In this system, increased milk production is treated as a commercial product. Data have also been collected for a group of farmers using traditional technology and are used for comparison.

The overall objective of the study was to evaluate the effects of MODP technologies on smallholder farm households and to identify policy options that would enhance beneficial impacts and mitigate harmful outcomes of the new technologies. Specific objectives were (a) to measure the food security effects resulting from the introduction of market-oriented dairy production technologies, (b) to assess the effect of market-oriented dairy production on incomes handled by women and its consequence on food consumption and (c) to evaluate the food marketed surplus effects of intensified dairying.

The agricultural household modelling approach was used to analyse the food security and food marketed surplus outcomes of the new technologies. Households may be modelled as either a single unit in the unitary model or as a collection of entities in the collective models. The econometric model was specified to allow the data to be consistent with whether household decision-making in the rural Ethiopian context was joint or whether the husband and wife made some decisions independently. A general examination of the unitary versus collective model is the income-pooling test, where the food consumption equation is a function of the total income and the wife's income. Holding the household income constant, the effect of the wife's income on food consumption can be interpreted as the impact of changing the share of household income allocated to the wife.

Panel data were collected in 1999 from 56 households in Holetta located 45 kilometres west of Addis Ababa. The households included a group of 27 with crossbred cows (CBC) and a group of 29 with locally bred cattle (LBC). Detailed household-level data were collected weekly (income, expenditure, production and distribution of dairy products and labour allocation to dairy production), monthly (food intake) and annually (demographics, land measurements, sample yields and distance to the crop market). The contrast between households using improved crossbred cattle and those using traditional cattle provided the basis for determining the extent to which the two sets of households allocated their resources differently and how their allocation decisions affected food security and food markete surpluses.

For the households considered in this study, there were significant differences in levels of income, food purchases, calorie intake and food marketed surpluses between the CBC and LBC groups. In households with LBC, women earned the entire dairy income from sales of butter in the local market but in households with CBC, women earned 59% of the dairy income and men earned 41%. This is due to the institutional requirement for household heads, mostly men, to register and collect payments from the delivery of milk to the Dairy Development Enterprise. Husbands in CBC households earned 58 Ethiopian Birr (US$ 1 = EB 8.5, at 15 May 2002) as monthly cash income from fresh milk sales, compared with zero for husbands in LBC households. Women in CBC households earned nearly 7 times more dairy income than women in LBC households, due to the same division of work, but where better opportunities produced increased output. The average monthly non-dairy farm and off-farm incomes between the CBC and LBC households were not statistically different, suggesting that the higher household income occurring in CBC households came mainly from dairy.

Average monthly per adult equivalent food expenditure was 36% higher for CBC than for LBC households. Women in both CBC and LBC households spent over 70% more income on food than men. With the introduction of MODP technologies, purchase of food by women in CBC households increased by 30% compared with 1% for men. Increased food purchases by women in CBC households implied that women's primary activities were enhanced. While women spent increased income on food, men used increased income for farm investment and non-farm expenditures.

Household members in CBC and LBC households were eating 94 and 72%, respectively, of the minimum calorie requirement for Ethiopia. However, CBC house holds consumed 30% more calories per adult equivalent than LBC households. Although these results show significant improvements in calorie intake levels for the CBC over the LBC groups, the seasonal pattern of calorie intake between the two groups was very similar. The fourth quarter of the year remained a serious deficit period implying that dairying with CBC improves, but does not mitigate seasonal consumption patterns in CBC households.

The marketed surplus analysis indicates that households with CBC were much more involved in the commercial economy. The CBC households had larger cash revenues from marketing of milk, dairy goods and other food surpluses, and larger market purchases of food. The value of marketed foods was 82% more for households with CBC.

Econometric estimation was done to evaluate the extent to which particular variables influenced food consumption, calorie intake, food marketed surplus and whether or not the effects differed for the CBC and LBC households. It was specified as a panel data model with household specific effects. The instrumental variable techniques for panel data developed by Hausman and Taylor (1981) were used to obtain consistent estimates of all parameters in the presence of correlation between individual household effects and a subset of the explanatory variables. The Wald statistic was used to test for equality of parameters between the CBC and LBC household equations.

The estimated regression results show positive and significant effects of MODP technologies on food security and food production. These effects are reflected mainly through their impact on incomes and wealth (measured by animal value and land area). Household incomes had a positive and significant effect on food consumption; the marginal tendency to spend on food was 0.034. The corresponding food consumption elasticity with respect to income, calculated at the mean, was 0.29. Animal value and cropland area, proxies for wealth and sources of a stream of permanent income, both had positive and significant influences on food consumption, with corresponding elasticities of 0.18 and 0.26. Income handled by women had no statistically significant impact on food consumption, implying the unitary model could not be rejected in the food consumption equation. Household size had a significant negative effect on food consumption, indicating that large households decrease the per capita share of the budget allocated to food.

The CBC group consumed on average 30% more calories per adult equivalent per day compared with the LBC group. The major difference in calorie intake between the CBC and LBC households (63%) was attributed to differences in the values of the explanatory variables, while the estimated parameter differences for the two groups accounted for only 37% of the difference. The role of MODP technologies on calorie intake was reflected most significantly by the value of animals. Animal value had a significant and positive impact on calorie intake in both the combined and the CBC regressions. The large increase in animal values for the CBC households was calculated to increase caloric intake by 12.7% relative to the LBC households. Household size has a negative and significant effect on per capita calorie intake in all three cases. The seasonal dummy variables were quite strong in all regressions. Nevertheless, there was no evidence of reduced seasonal effects between the LBC and the CBC households, i.e. CBC improved calorie consumption in all seasons compared with LBC, but CBC could not fully mitigate consumption patterns between seasons.

The value of surplus food marketed quarterly by the CBC group was 82% higher than that by the LBC group. Seventy-six per cent of the increase in the value of marketed surplus food for the CBC over the LBC groups was accounted for by the difference in household characteristics, while only 24% of the increase could be attributed to differences in the estimated parameters. The elasticity of marketed surplus with respect to household income was positive. Evaluated at the sample mean, a 10% raise in income increased marketed surplus foods by 6, 5 and 9%, for the whole sample CBC and LBC groups, respectively. Both income in the hands of women and animal value had positive and significant effects on market surplus. And distance to the crop market had significantly negative effect on marketed surplus.

In conclusion, households that used the market-oriented dairy production (MODP) technologies increased their income and animal values significantly, relative to households using traditional dairy production methods. The increased resources led to significantly higher food consumption, calorie intake and marketed surplus. Although intensified dairying improved the calorie intake level of CBC households throughout the year, there was no significant seasonal consumption mitigations. The significantly increased marketed surplus, however, has the potential to improve diets of non-dairy households.

1 Introduction

1.1 Background and justification

The Green Revolution increased cereal production, farm income and food availability in developing countries between 1960 and 1990. Despite the increase in cereal production, 25 developing countries were unable to assure the minimally adequate food energy needs of 2200 calories/person per day for their populations in the late 1980s (Pinstrup-Andersen 1994). Today an estimated 840 million people, 20% of people in developing countries, are food insecure (FAO 1996b). These people consume fewer than 2700 calories/adult person per day, live in permanent or intermittent hunger and are chronically undernourished. The food insecure are the poor, who do not have sufficient resources to produce or the income to acquire adequate quantities and qualities of food, at all times, to ensure active and healthy lives.

Commercialisation of cereal production by smallholder farms has been found as a potential means of improving the food security and well being of the households in low-income countries (von Braun and Kennedy 1994). Although livestock production is a major activity in crop–livestock mixed farming systems in many developing countries, the potential for smallholder livestock development for alleviating poverty and food insecurity has received inadequate attention. In developing countries, livestock provide high quality food, cash income and employment. Livestock ownership also significantly impacts on farm productivity through provision of draft power and manure for fertiliser in crop production. Livestock ownership helps sustain farming and economic stability. It is a major form of investment and a source of livelihood for many farmers at times of drought, flood and other form of natural calamities. Livestock is also important in the social and cultural lives of millions of small-scale farmers as a symbol of wealth and for use in many ceremonies (Sansoucy et al. 1995). However, livestock productivity in developing countries is low and therefore livestock development has the potential to contribute to alleviate poverty, increase food security and improve people's health.

The combination of higher demands for livestock and livestock products, greater number of people and less space, is resulting in the transformation of the livestock sector in many developing countries. A strategy being advocated to support smallholder dairying is the intensification of dairy production in mixed farming systems (Walshe et al. 1991; Winrock International 1992; FAO/ILRI 1995). Traditional resource-based animal production systems in which remote pastures, grasses indigestible by humans and backyard refuse are converted into high value animal products are being substituted by input intensive, science-based animal production systems. These systems have the potential to raise growth rates of output and cash incomes, improve food security, and reduce environmental degradation.

One such system, market-oriented dairy production (MODP) technologies involving the introduction of crossbred cows and the utilisation of complementary feed and management technologies for increased dairy production, is being undertaken in the Ethiopian highlands and in many developing countries, particularly in peri-urban areas.

In this system, increased milk production is treated as a commercial commodity as milk sales generate regular cash income. Market-oriented dairying has many food security-related benefits for peri-urban smallholder communities. For producers, these include increased food availability, regular cash income and creation of employment and for consumers, an increased high quality food supply and more employment opportunities. Food security impacts from the use of MODP technologies could be realised directly through higher consumption of dairy products or indirectly through the use of increased cash incomes to purchase more or better quality foods or both. Increased cash income can help purchase clothing, health care and education and can also help purchase inputs for crop production, thus increase food availability.

Dairy production is a critical issue in Ethiopia—a livestock-based society—where livestock and its products are important sources of food and income, and dairying has not been fully exploited and promoted. The greatest potential for new technologies in dairying is expected in the highlands of Ethiopia and other sub-Saharan Africa and Asian countries, due to low disease pressure and good agro-climatic conditions for the cultivation of feed. High population densities and animal stocking rates, as well as easy access to markets, make it attractive to invest in MODP technologies in peri-urban areas in these regions.

Ethiopia has experienced the compounding effects of civil strife, drought and famine during the past thirty years. Poverty and malnutrition are obvious in the rural areas of the country where, paradoxically, most of the population is engaged in small-scale subsistence-oriented farming. This is also the case for the Ethiopian highlands, a region well known for its outstanding biophysical farming potential. It has been suggested that Ethiopia could theoretically support two to four harvests a year, which would turn it into the granary of East Africa and the Near East (Steglich 1998). Yet, agricultural productivity remains low. In addition, population growth and soil degradation have increased pressure on scarce land resources. The rural population of Ethiopia suffers from severe chronic malnutrition, highly prevalent even in food surplus regions (CSA 1992). The number of malnourished population in Ethiopia is among the highest in the world. They often lack sufficient amounts of protein and energy in their diets, as well as micronutrients such as iodine and vitamins (UNICEF 1993). The Ethiopian Government and international agencies are most concerned about the food shortages and the high levels of malnutrition.

1.2 Problem statement

Market-oriented dairy production has been shown to substantially raise milk production and household incomes where development efforts are demand-driven (Walshe et al. 1991; Thomas-Slayter and Bhatt 1994; Pankhurst 1996; Shapiro et al. 1998). It has been shown that if more dairy products are available and consumed, there will be positive effects on human nutrition (Neumann et al. 1993). However, the food security effects of increased milk production and incomes on the active household may also depend on intra-household resource allocation, income distribution and expenditures made with the increased income. While smallholder intensified dairying may have positive impacts on milk production and cash incomes, questions remain about the extent to which increased cash flow is spent on more and better quality food, and seasonal[1] food consumption is mitigated as a consequence.

MODP technologies also have supply-side effects, e.g. the potential to increase whole farm productivity through the use of manure as fertiliser, the use of animals for traction and the use of increased cash flow to purchase more feed and crop inputs. The whole farm productivity effect of MODP technologies has not been evaluated, though it is important for the complete assessment of the effect of the new agricultural technologies. This study analyses the food production effects of intensified dairying in Ethiopia through the appraisal of food marketed surplus changes.

Most studies, evaluating the impact of new technologies and commercialisation of small-scale farming on food and nutrition security, combine data across agricultural production stages (harvesting and pre-harvesting). Behrman et al. (1997) point out that such studies may result in false estimates for any particular production stage and obscure the possibility that measures directed at certain agricultural stages might be much more effective at reducing calorie deficiencies than those directed at other stages of the production cycle. The seasonal variation in the calorie intake effect of MODP technologies is unknown. As a result, policy-makers do not know where and when the food security effects of dairy production growth opportunities are the greatest, and what policies are most critical to their realisation. This research addresses the food security (via food consumption and calorie intake) and food production (via food marketed surplus) effects of the new technology and identifies policy options that enhance positive effects.

1.3 Research objectives and hypotheses

The overall objective of this study is to evaluate the effects of MODP technologies on smallholder farm households and to identify policy options that would enhance beneficial impacts and mitigate harmful outcomes of the new technologies. Specific objectives are to:

- measure the food security effects resulting from the introduction of MODP technologies
- assess the effect of market-oriented dairy production on incomes handled by women and its consequence for them and on food consumption and
- evaluate the food production (food marketed surplus) effects of intensified dairying.

The following hypotheses corresponding to the objectives were tested:

- Market-oriented dairy production may contribute to food security, directly through increased livestock, dairy products and crop production and, indirectly through

1. The word 'season' is often used to refer to a complete crop cycle. It is also used to refer to stages of production within a crop cycle, such as the harvesting and planting periods. Season is used here to refer to the different stages of production.

increased cash income from the sale of surplus dairy and other farm products. It can also generate employment that enables purchases of more and better quality foods.

- MODP, a commercial activity, may result in the transfer of dairy incomes, traditionally obtained by women to men, from the marketing of home produced butter and cheese. This may have adverse effects on women and on household food consumption, where food purchase is a woman's responsibility.
- The introduction of MODP raises income through the sale of increased dairy outputs. When this additional income is used to purchase crop and livestock inputs, production of agricultural products may increase, thus raising food marketed surplus.

These hypotheses were tested with data from the Ethiopian highlands where research is being conducted to assess the biological performance of crossbred cows in farm conditions and its effects on human welfare.

The remainder of the paper is organised as follows. The next section briefly describes the Ethiopian agricultural sector and the study area and gives an overview of the dairy development project in Holetta. This is followed by a discussion of the effect of technological change and commercialisation of semi-subsistence agriculture on food security (Section 3). The conceptual and analytical frameworks including the empirical models are presented in Section 4. A description of the data, data collection method and descriptive analysis are presented in Section 5. Econometric results and interpretation are presented in Section 6. Conclusions are drawn in Section 7 along with policy implications and suggested areas for future research.

2 Agriculture in Ethiopia and the study area

Agriculture is the dominant sector of the Ethiopian economy contributing 45% of the GDP, 80% of the employment and 85% of the total export earnings (FAO 1993, Annex 1.1). The balance of trade has been negative for the past couple of decades. Although there were high import restrictions, imports exceeded exports by almost 66% in 1997 (World Bank 1999). The major source of foreign exchange is coffee, providing 65% of the export earnings. Other agricultural export products are oilseeds, pulses, cotton, sugar cane, fruits, flowers, hides and skins and livestock, mainly sheep and cattle. Natural resources like gold, platinum, copper, potash and petroleum exist, but exploitation of these minerals has not been done on a large scale (Gryseels 1988).

Ethiopia has the largest livestock herd in Africa and accounts for 17% of cattle, 20% of sheep, 13% of goats and 55% of equines in sub-Saharan Africa (SSA) (FAO 1993). Livestock contributes 16% of the GDP and 30% of the agricultural GDP (FAO 1996a). Seventy per cent of cattle, 75% of sheep, 27% of goats and 80% of equines are found in the highlands (Gryseels 1988).

The agricultural system is divided into smallholder mixed farming in the highlands and pastoralism in the lowlands. The highlands cover only 40% of the total land area but contain 88% of the human population and account for 94% of the regularly cultivated cropland, 70% of the livestock and 90% of the country's economic activities (Gryseels 1988). The highlands are favoured by good soil and suitable climatic conditions for farming. The climate is temperate, rainfall well distributed and disease incidence low, thus supporting higher productivity and population densities than the lowland areas. The highlands thus provide suitable conditions for the introduction of high yielding plant varieties and exotic animal breeds, allowing for intensification of agricultural production (Zinash and Bediye 1991, p. 129). Despite this potential, the agricultural sector's performance has been disappointing in recent years. The average growth rate in agriculture between 1980 and 1991 was 2%, which is significantly lower than the rate of population growth (Berhanu and Berhanu 1999/2000).

The physical resources of the highlands are at risk. For example, land degradation has been rapid. In 1986, the Food and Agriculture Organization of the United Nations (FAO 1986) reported over 200 million tonnes of soil were being lost annually and threatened the sustainability of the farming system. The productivity of the livestock sector was being affected. Its productivity was lower than the African average: live weight gains are low, at about 20 kg annually and mortality high, at 20% (FAO 1993).

The high human population growth rate of 2.6% annually added to the high rural to urban migrations are expected to alter food production, marketing and consumption. Population pressures on fixed agricultural land will drive crop and livestock production towards intensification. Growth of population and urbanisation will increase the demand for foods because urban dwellers produce little of their own food. Therefore as more people live in urban areas, the demand for food will create markets for produce and encourage commercialisation of agriculture. As farming moves from subsistence towards commercialisation, greater specialisation in production, transportation and marketing will occur, making the process more efficient. The challenge is to achieve food security for the prospective population. There is scope for intensification of agriculture and more productive use of resources through the introduction of improved technology supported by more favourable policies and better infrastructure (Winrock International 1992). An example of such an innovation is market-orientation of smallholder dairy production.

2.1 The study site

This study was conducted in eight Peasant Associations (PA) in the Wolmera and Ejere *woredas*, in the central highlands. These PAs are situated within a 5–15 km radius of the Holetta town, which is 40 km west of Addis Ababa. The area is positioned along the Addis Ababa-Ambo tarmac road, providing access to weekly markets in Holetta (capital of Wolmera) and Menagesha (one of the three towns in the *woreda* besides Holetta and Burayu). A larger research station of the Ethiopian Agricultural Research Organization (EARO) is located at Holetta. The elevation of the Research Station is 2400 metres above sea level (masl) in a high-potential, cereal-livestock zone in the Central highlands of Ethiopia. About 90.3% of the soil in the *woreda* is Chromic and Orthic Luvisol, with high water holding capacity and good agricultural potential. The remaining 9.7% of the soil is Chromic and Orthic Vertisol; it is poorly drained and has limited agricultural potential). The soils are heavy and sticky when wet and hard when dry. Sufficient power is needed to till the soil, thus the prevailing use of animal traction. Water logging in depression and soil erosion on slopes are serious problems inhibiting crop growth.

Holetta receives an average annual rainfall of 1100 mm (Hailu et al. 1990). The rainfall is bimodal: short rains, *belg*, from February to May and long rains, *meher*, from June to September. The short rains are mainly used to break and prepare the soils for crop cultivation. The pattern of rainfall dictates the single cropping period, starting in March and ending in December. The mean maximum and minimum temperatures are 22.5 and 6.3°C, respectively, and average temperatures range between 11.6 and 15.3°C (Buta 1997).

Orthodox Christians dominate the Wolmera and Ejere *woredas*. Religious holidays, including Sundays, are strictly recognised. This limits the fieldwork of the farmers, who observe about 144 religious days a year. The religious restrictions normally relate to cropping activities that involve breaking of the soil, such as ploughing, weeding and harvesting and threshing. The average working days in crop production related activities, including hay making, are 222 in any crop year. Of these days, about 74 days are in the rainy period between June and September and the remaining 148 are in the dry and short rainy seasons of the year. Except for small children, consumption of animal protein is forbidden on Wednesdays and Fridays every week and during 55 days of fasting between February and April and 15 days in August. Most of the milk during this period is processed into cheese and butter for later sales and consumption.

Smallholder mixed crop–livestock farming is the dominant mode of production in the area. The system is oriented towards providing subsistence requirements for the farm household. The family is a production and consumption unit. Although about 80% of all crops produced on the farm are consumed at home (Getachew and Shapiro 1993), the market plays a significant role giving farmers the opportunities to sell agricultural surpluses and to buy products that are not produced on-farm. It is also a meeting place for relatives and friends and for the exchange of information (Dessalegn 1991).

In 1996, 41% of the total land in the Welmera *woreda* was cultivated and 19% was used for grazing. Farmers produce a mixture of cereals, pulses and oil crops. Teff, barley and wheat are the commonly grown cereals. Maize, oats and sorghum are grown in smaller quantities. Legumes grown include horse beans, field peas, lentils, rough peas, chickpeas and vetch. Oil crops such as *noug*, linseed and rapeseed are grown in small quantities in the cultivated areas. Vegetables such as onions, potatoes, cabbage, carrots, garlic and false banana (*enset*) are grown on smaller scales, generally in backyard gardens.

The fertility of the soil is poor, except for *kossi* land.[2] Most of the cultivated land has been ploughed continuously for a long period because of high population pressure. The problem is compounded by the limited use of fertiliser and manure and the reduction in the frequency and length of fallow periods. As a consequence of wood scarcity, dung is normally used as fuel for cooking rather than manure. Farmers practice crop rotation and use inorganic fertiliser as means of maintaining soil fertility. The Ministry of Agriculture supplies limited quantities of fertiliser (DAP and urea), along with improved seeds, herbicides and pesticides on a credit basis.

Cattle, sheep, equine and poultry are important components of the farming system. Oxen plough all the cropped land. Cattle are mainly kept to supply and replace draft oxen. Livestock dung is used as fuel and building material. Meat, milk, hides and skins are important sources of food and income. Livestock provide security during periods of crop failure when they are sold to purchase grain. Cattle are the most important species in terms of monetary value and contribution to the farming system. Mutton is the main source of meat and sheep are a major form of investment. Donkeys are the prime transporters of agricultural products, while horses and mules are used for human transport.

Gender division of labour is fairly distinct in the study area. Unlike in western and southern Africa, women in Ethiopia do not play a dominant role in crop production. Men do more than 75% of the crop production activities. Ploughing, seeding, seed covering and herbicide application are exclusively done by men. Women and children help in weeding, harvesting and transport of pulses. Women are also responsible for preparing threshing grounds and for constructing containers for storing crops, *gotera*. They also assist in threshing and winnowing and are active in the marketing of grains, vegetables and pulses. Revenues are used to purchase needed household items. Women cultivate backyard vegetable gardens.

Men, women and children also contribute significantly to livestock rearing. Men participate in the herding of animals, barn cleaning and sometimes in milking. Milking, processing and sale of milk are primarily women's responsibilities. Women also collect,

2. This is land around the homestead, where organic waste is deposited.

make, dry and sell dung cakes. Herding is mostly the task of children between the ages of 10 and 16 years. They also assist in milking, barn cleaning and in the collection and making of dung cakes. In addition to agricultural tasks, women perform domestic chores, such as preparing and processing food, fetching water, collecting wood for fuel, cleaning, washing and caring for children, the sick and the elderly. Women plaster walls and floors and also raise extra cash by brewing local beer, *tella*, and local whisky, *katicalla*.

Although livestock plays an important part in the traditional farming system, its productivity is low. Native cows first calf at an average age of over 4 years and at an interval of 20 months (Darnhofer 1997). Some of the main problems farmers face in raising animals are shortage of grazing land, limited veterinary services and a general shortage and high cost of feed and exotic breeds. The primary sources of animal feed are grazing and crop by-products. In addition, cattle are given minerals (ordinary salt) and sometimes by-products from the production of *tella* made from barley. Hay is also used, but because its harvest coincides with the harvesting of the *meher* crops, labour shortage is a problem, leading to poor quality hay. Animals are fed differently on the farm. The hay and straw are normally saved for working animals, such as oxen used for ploughing or threshing, or lactating cows. Small ruminants and equines are mostly grazed (Darnhofer 1997).

2.2 Dairy development project in Holetta

Improved dairy production using crossbred cattle and better feeding and management has been introduced by the Ministry of Agriculture (MOA) in parts of central highlands, especially in the Addis Ababa milk shed. The conditions in the Ethiopian highlands are well suited to dairy animal management because of the favourable climate, controllable pest and disease situation and high production potential for integrated agriculture. It was selected as the development strategy because farming families cannot increase their incomes via expansion in crop production or improving forestry because of the dwindling land holdings.

However, limited land and high pressure of a large indigenous livestock population on available feed resources mean the productivity of these animals is low. Studies hypothesised that if improved cows could be used for both milk and draft power, the number of livestock on a farm, particularly draft animals, could be reduced and consequently overall herd productivity could be increased. To test the hypothesis, a project was implemented in the Holetta area by EARO and ILRI to develop technologies that would enable smallholder mixed crop–livestock farmers to participate in commercial agricultural activities that can have a significant impact on sustainable food production, food security, farmer incomes, and human nutrition, through substantially increased milk production. The project was based on the use of crossbred cows for dairy and possibly draft power. Crossbred dairy cows were introduced along with improved animal husbandry and intensified feed production technologies as a means of increasing milk production and incomes.

On-station research was conducted during 1989 to 1993 to determine if there was a trade-off between traction and milk production and to develop strategies for feeding crossbred cows for both milk production and traction to increase their overall efficiency. The research results indicated that with appropriate feeding regimes, dairy cows could be used for draft purposes without significant detrimental effects on lactation or reproduction, but the calving interval would be extended. High productivity indices for well-fed working crossbred cows indicated that the technology has the potential to reduce stocking rates, particularly reduce the need for draft oxen, increase efficient use of on-farm resources, and raise farm productivity (Zerbini et al. 1998).

In 1993, on-farm testing of the technology in villages around EARO's Holetta research station was started in a joint effort with 14 farmers, half using crossbred cows for milk production only and the other half using crossbred cows for both traction and milk production. The purpose was to establish whether and how crossbred cows requiring new feed production and feeding strategies could be managed for dual purposes under real farm conditions. Another objective was to evaluate the economic performances (investment returns) of crossbred dairy cows on smallholder farms and their impact on total household resource use, including labour.

Implementation of the on-farm trials involved the following major activities, described by Larsen (1997) and divided into six packages, mostly carried out in close collaboration with extension personnel and veterinarians from the Zonal and *woreda* offices of the MoA:

- Improved genotype: A pair of F_1 crossbred cows (Holstein–Friesian × Boran or Simmental × Boran) with large body frames and a higher production potential than the local cows was provided to the project farmers on cash and credit at subsidised prices.
- Forage package: Farmers were advised to plant a minimum of half an hectare of oats and vetch for hay production each year. In addition, a backyard forage package was developed recommending that farmers plant Napier grass, fodder (Tagasate and Sesbania) and fodder beets on their compounds.
- Health package: The project provided drugs and veterinary services, at subsidised prices. The health scheme consisted of regular administration of vaccination, deworming and spraying procedures as well as routine visits to all project farmers. Farmers were advised to use improved practices. Emphasis was on advising farmers to improve hygiene procedures and practice restricted grazing.
- Breeding package: The scheme consisted of heat detection, timely insemination, pregnancy testing and control of reproductive diseases. All project cows were served with 50% Friesian × Boran or Simmental × Boran semen through artificial insemination (AI). The offspring were served either with crossbred bulls (50%) or with local bulls. The aim is to maintain a population close to 50% exotic blood on farm.
- Improved management of crossbred animals, milk and dairy products: This package involved training at the Holetta Research Station on the following aspects: stall feeding, calf rearing, crossbred cow management, milking, milk handling, processing

and marketing of dairy products, cow traction, manure handling and construction of improved barns.

- Training package: The aim of this package was to increase the farmers' awareness of the advantages and constraints of the new technologies. A secondary objective was to obtain direct feedback from farmers on the use of the new technology, i.e. farmers were to co-operate with the enumerators in their daily recording of data for the duration of the project.

In 1994, intensive biological and socio-economic data were collected. Whole farm analysis, based on the concept of the farm as a system, indicated that it was feasible and profitable to use crossbred cows for both milk production and traction (Buta 1997). The analysis showed traditional gender division of labour for various farming activities and revealed that total household labour input for farms with crossbred cows would increase, compared with local livestock rearing, but it did not show what changes would occur by gender.

Prior to the introduction of cow traction, only oxen were used for traction in the study area. EARO and ILRI felt the need to find out whether farmers would be willing to use cows for traction, since it was not a traditional practice. Thus in 1993, an anthropological study was carried out at the on-farm testing site of 52 farmers, including the 14 who received crossbred cows, without prior experience, to understand their attitude on the use of crossbred cows for the dual purposes of milk production and traction. The study was conducted in the periods just before and just after most of the 14 selected farmers received their crossbred cows. Only 19% of the farmers surveyed thought it was feasible to use cows for ploughing (Pankhurst 1993). In this survey, household members' attitudes and perceptions about the technology on their welfare were not solicited, although it would have implications for their workload, income and food and nutrition security. Whether discussions with all members of a household would have changed their decisions about dual use of cows was not known.

In 1995, the on-farm research programme was expanded to study the effects of resource endowment on the utilisation of dairy–draft technology. In order to select farmers to participate, volunteers were sought from a number of villages. Fifty-nine farmers were selected—30 with crossbred cows and 29 with indigenous cattle. The selection criteria included the willingness to 1) use crossbred cows for traction and milk production, 2) plant and use improved fodder and forages, 3) use artificial insemination and veterinary services, 4) practice improved management of cows, calves and milk and 5) share information with the project. The participating farmers were stratified according to their resource endowment—rich, medium and poor. Observation of the initial 14 farmers indicated that the sexes and ages of household members were important variables. At this stage, along with the biological data, on-farm monitoring also included data on intra-household resource allocation, task sharing, income generation and expenditure patterns.

While preparing for the expanded on-farm testing programme, another anthropological survey was conducted in 1995 to assess the acceptability and potential diffusion of the new technology and to understand the attitudes of the farmers selected by the project in 1993 and 1995 (Pankhurst 1996). The study attempted to verify whether there had been any change in farmers' attitudes towards the use of crossbred cows since the previous survey of 1993 and to identify the likely innovators of the new technology to predict which of the selected farmers were likely to be the most successful adopters. The survey showed that 51% of the farmers believed that crossbred cows could plough and give milk simultaneously. Forty per cent of the farmers believed that using cows for ploughing would result in a decrease in milk yield. A few farmers even suggested that milk yields would increase after traction because the body of the cow would be relaxed. Some claimed that ploughing and milk production were complementary, since cows that plough eat more and hence give more milk. It was the younger, more educated and smaller landholders who believed crossbred cows could plough and produce milk (Pankhurst 1996).

Dairying with crossbred cows could have a positive impact on human nutrition, both directly via consumption of increased milk and dairy products and, indirectly via sale of increased output and the purchase of more and better quality food. In traditional cattle production systems, local cows produce 2–3 litres of milk per day, part of which is consumed and the rest sold as butter or cheese, processed by women. Crossbred cows produce 6–8 times more milk per day than traditional cows. More milk was sold and consumed by households with crossbred cows than with traditional cows. In 1997, additional questions on food consumption, nutrition and health were added to the on-going survey to assess the effect of intensified dairying on human nutrition, particularly of children.

In July 1999, an informal survey was conducted by EARO and ILRI to assess and evaluate the utilisation of the dairy–draft technology in the Holetta area. A total of 83 farmers were interviewed, consisting of 29 project farmers, 28 control farmers and 26 non-project farmers.[3]

Project farmers indicated that they had obtained numerous benefits from participating in the project (Alemayehu et al. 1999), some of which included:

- Improvements in livelihood due to higher consumption and sale of milk and dairy products. This was only apparent after the introduction of crossbred cows.
- Regular source of income enables farmers to pay off farm loans from the MoA, due immediately after harvest, without having to sell produce at typically low prices in post harvest periods. The higher cash flow also made it possible for some farmers to hire labour.
- Improved knowledge of modern livestock management, milk handling and processing, improved milk hygiene and increased sales of milk to the Dairy Development Enterprise (DDE).

Although farmers expressed benefits from the project, they also stated its weaknesses, which were as follows (Alemayehu et al. 1999):

- Using crossbred cows for traction reduced milk yields and increased calving intervals. Other farmers did not see the need to be overburdening cows when oxen could be

3. Project farmers were those who participated in the dairy–draft project and had obtained crossbred cows for milk production and draft use. Control farmers were farmers participating in the project, but who did not have crossbred cows. The third group represented non-participants.

used. They added that the natural purpose of the cow was to give milk and have calves. In fact, most farmers discontinued the use of cows for traction after fulfilling the requirement of the project.

- Farmers with crossbred cows were not properly trained on how to use them for traction and were not getting timely breeding services, resulting in reproductive inefficiency and less profit from investments.
- Crossbred cows are more susceptible to diseases and nutritional deficiencies and need more feed and water than the indigenous breeds.
- Seeds of improved forages are scarce and their prices are high.
- High feeding requirement of crossbred cows was remarked. Farmers noted that utilisation of crossbred cows increased labour requirements, which sometimes compete with crop production.
- Low milk prices from DDE, the only regular purchaser of liquid milk, was forcing farmers to sell milk privately and face price variation. For example, during the fasting periods, the demand for milk falls thus causing farmers who do not supply milk to the DDE to process it to cheese and butter.
- The prices of concentrates such as oil seed cake, wheat bran and wheat middling have been rising over the last few years, while the quality and availability of feed have been declining.

Overall, farmers expressed the willingness and need to keep crossbred animals for milk production. They suggested that veterinary and breeding services be improved and Napier grass and fodder beet seeds be made more accessible for successful dairy production.

Crossbred cow technologies have food security, intra-household resource allocation (e.g. labour) and increased agricultural marketable surplus effects in the region. These impacts were analysed in this study using data collected in 1999. The aims of this study were to identify policies that could minimise the potential adverse effects and enhance benefits of MODP technologies on food security and agricultural production.

3 The role of technological change and commercialisation of semi-subsistence agricultural production in achieving food security

The most widely recognised definition of food security is access by all people at all times to enough food for an active, healthy life (World Bank 1986). This implies *accessibility* and *stability* dimensions. Accessibility refers to the ability to either produce or purchase the needed basic foods.[4] Stability implies lack of variation in access to the basic foods. It includes a time factor, distinguishing chronic and transitory household food insecurity. Food security has strong links with issues of poverty, employment and income generation. For developing countries, where more than 70% of the population lives in rural areas and depends on agriculture for its livelihood, increasing food production and commercialisation of agriculture are the cornerstones for increasing food security and economic development. (See Tangka 2001 for a discussion of the evolution, types, levels and dimensions of food security).

The impact of commercialisation of semi-subsistence agriculture on food security has been widely debated in the literature. The International Food Policy Research Institute (IFPRI) has undertaken numerous micro-level studies in Africa (e.g. Kenya and The Gambia), Asia (The Philippines) and Central America (Guatemala) to assess the effect of the commercialisation of agriculture on crop production, income, expenditures, food security and nutrition goals (Kennedy et al. 1992). The aim of these studies was to analyse the process of cash cropping in order to identify key factors that determine food security and nutritional outcomes, with the objective of formulating policies to enhance the beneficial effects of commercialisation and minimise the harmful effects.

Increased market integration of semi-subsistence agriculture is part of a development strategy oriented towards growth. Market orientation of small-scale crop production has positive impacts on food security and household incomes. However, much of the available literature focuses on the commercialisation effects of semi-subsistence crop production with little attention given to the effect of market-oriented livestock production and dairying. This is inappropriate for societies where livestock is an important source of food and income. The introduction of market-oriented livestock technology, especially dairying, is one of the principal means through which the welfare and food security in mixed crop–livestock systems, such as that of Ethiopia, can be improved. It has the potential to contribute to the accessibility and stability elements of food security, via increased output of livestock and non-livestock agricultural products and through employment and income generation that may assure access to food (Sansoucy et al.

4. The literature distinguishes availability and accessibility dimensions of food security. Food availability is said to be determined by the level of food supplies, i.e. subsistence production and market supplies from domestic production, food stocks and food imports. Access to food is referred to as the ability to express food needs (beyond subsistence production) as effective demand (Thomson and Metz 1997).

1995). The effects of intensified dairying in the Ethiopian highlands on food security (accessibility and stability dimensions) and food marketed surplus are examined in this study.

3.1 Livestock and food accessibility

Livestock production enhances food availability directly and indirectly. It directly increases food supply by making livestock products available for consumption, if farmers can forego cash income from marketing these high-value products. Animals are important sources of high quality protein, minerals, vitamins and micronutrients, essential for balanced growth. Meat, milk and eggs provide 17 to 18% of the dietary protein in African diets (Winrock International 1992). Quality foods of animal origin enhance human growth and development, particularly of children in chronically mild to moderately malnourished populations, because they contain amino acids absent in cereals and essential to human health. In developed countries, animal products provide about 60% of the dietary protein, compared with 22% in developing countries. In developing countries, animal products are important in preventing malnutrition as they are concentrated sources of amino acids not found in vegetable proteins or frequently eaten staple foods. Animal products contribute 30% of total calories in developed countries and less than 10% in developing countries (Sansoucy et al. 1995).

Livestock indirectly increase the availability of food by providing inputs for crop production. For example, livestock supplies draft power for ploughing and other farming-related activities like threshing and water lifting. In the highlands of Ethiopia, there is a positive correlation between draft animals and crop production (Omiti 1995). Crop production on farms with inadequate traction power has low quality tillage, which encourages the use of low-value crops requiring less tillage (Sansoucy et al. 1995). Crossbred cows, which can be used for both milk production and power, can potentially increase efficiency by requiring fewer animals. Such cows when used for ploughing, however, need to be properly fed to minimise traction effects on milk production and reproduction (Zerbini et al. 1998).

Livestock also indirectly increase food availability by providing manure, the principal source of fertiliser available to a large number of small-scale farmers. Animal manure used as fertiliser increases crop production. Though manure cannot replace all the soil nutrients removed by crops, it recycles a significant proportion. In addition it provides organic matter to the soil, helping to maintain its structure, water retention and drainage capacities. Part of the manure is converted to dung cakes and used as fuel for cooking. In parts of South and South-East Asia, biogas from manure is an excellent source of energy and effluent from bio digesters form an important source of fertiliser. Furthermore, as livestock production is intensified, leguminous fodder plants and trees grown to feed livestock provide nitrogen for crop production (Sansoucy et al. 1995).

In developing countries, livestock production is a major source of income. For many mixed, smallholder farming systems, livestock is an important 'cash crop' (Sansoucy et al. 1995). The amount of income varies across regions and production systems, depending on the species and the roles of livestock in the system (Jahnke 1982). Cash can be obtained from the regular sale of milk, eggs, butter, cheese and dung cakes and occasionally from the sale of live animals, wool, meat, hides and skins as well as from services such as draft power and transport. In the mixed farming system of the Ethiopian highlands, sales of livestock and livestock products account for 83% of the cash income per year (approximately 52% from animals and 31% from livestock products). Dairy products account for over 50% and manure for 25% of the sale of livestock products (Gryseels 1988).

An important part of the income obtained from animal husbandry is spent on food, agricultural inputs and other family needs (Sansoucy et al. 1995). This is particularly important for pastoral households for whom the terms of trade between livestock and grain is a major indicator of food security. Livestock keepers also exchange high value commodities like meat, eggs or milk for cheaper and larger quantities of food, such as local cereals and vegetables (Bouis and Haddad 1990).

3.2 Livestock and food stability

Livestock production gives increased economic stability to farm households. Small ruminants serve in part as a cash buffer and large animals as capital reserves and a hedge against inflation. In mixed farming systems, livestock can also serve as a form of insurance against the risk associated with crop failures, by providing alternative sources of food and income. As an asset, livestock can be liquidated at a time of great need to stabilise food production and consumption (Sansoucy et al. 1995). In addition, the frequent cash flow from the sale of milk and eggs adds to household economic stability and has been noted as an important determinant of food security (von Braun and Kennedy 1994). The view that livestock serves as insurance has been questioned by Lim and Townsend (1994, in Townsend 1995). Using data collected by ICRISAT from India, Côte d'Ivoire and Thailand, their findings suggest that sales and purchases of livestock do not mitigate income fluctuations (Townsend 1995).

4 Conceptual, theoretical and analytical framework

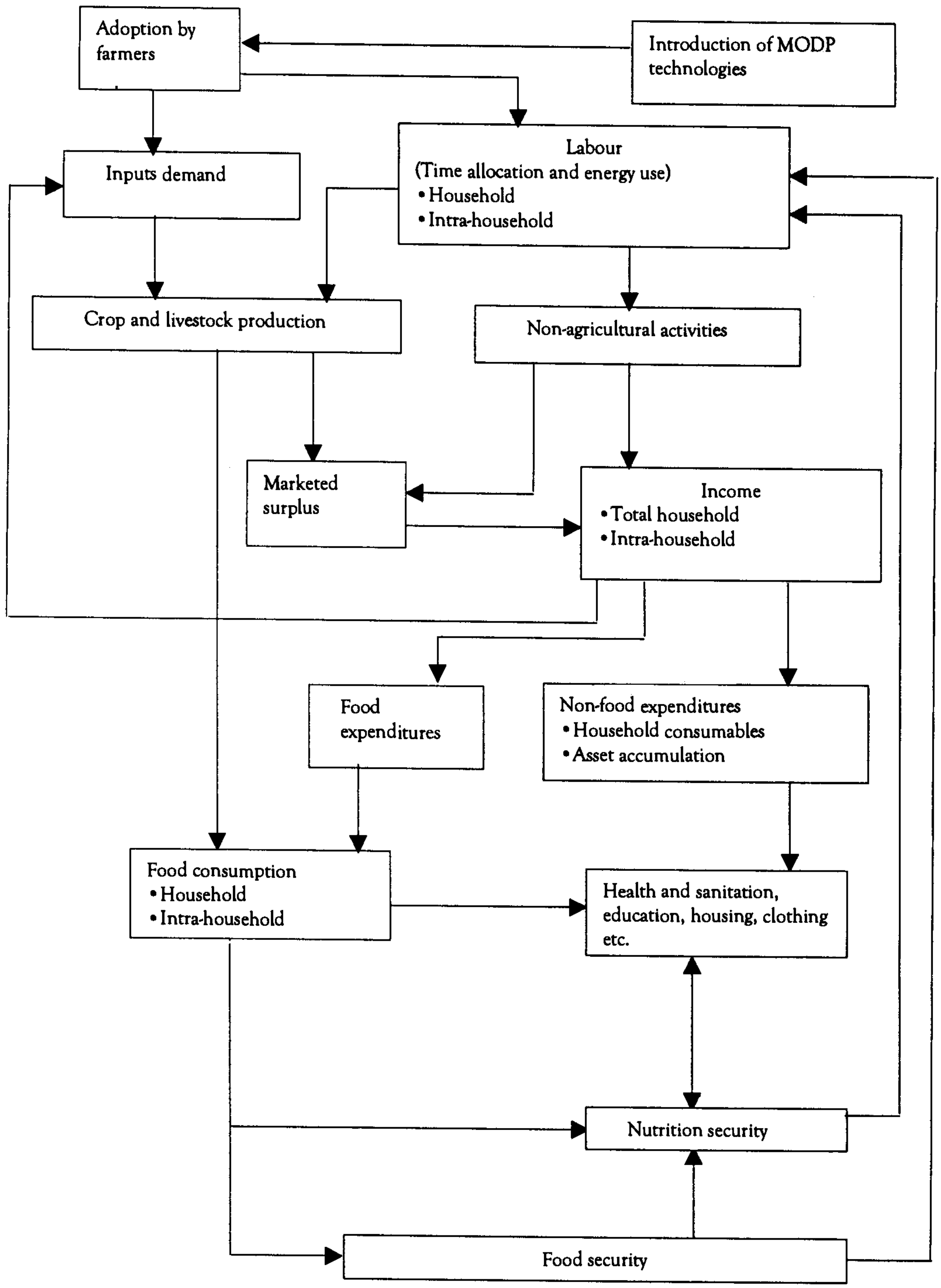
4.1 A conceptual framework for linking intensified dairying with food security

The pathways through which agricultural change can potentially influence food security and agricultural production are illustrated in Figure 1, based on the assumption that the household has already decided to intensify dairy production. The factors that influence this decision include a change in the farmer's incentive structure, resource endowment of the farm household and a response to positive economic signals, which increase the demand for cash income versus in-kind (food) income. Incentives that favour increased dairy production are: the provision of credit and subsidies, a market for dairy products, feed availability and provision of veterinary services and the training of farmers on how to manage high yielding cows.

The effects of technological change and commercialisation of smallholder dairying on food security are mediated through (i) the attributes of the new technology, (ii) the utilisation process, (iii) its production and resulting time and household resource allocation and employment effects, (iv) expenditure patterns and food consumption, which may vary among households and across production stages and (v) the health and sanitation environment that impinges on nutrition.

The most direct link between technological change in smallholder agriculture and food security is increased household food availability from own production, which is incremental in-kind income from 'cash crop' production. In other words, dairy development schemes can directly contribute to food security by making more milk available for home consumption. Small-scale dairy producers have sometimes been observed, however, to sell expensive calories (milk) and increase net purchase of cheaper calories (cereals), thereby increasing food consumption (Alderman 1987).

The prominent link between intensified dairying and food security is the income-food consumption link, where increased income facilitates increased food consumption. However, this is not automatic as intra-household decision-making processes, on resource and benefit allocation and resource endowments of the household, play an important role in the relationship between increased income and improvements in food security. The link between increased income and food security depends on labour and time allocation between agricultural and non-agricultural activities, allocation of income between food and non-food expenditures and how the available food budget is spent, i.e. which types and quantities of food are purchased. A better understanding of these critical relationships is crucial to the identification of efficient modes of intervention designed to improve food security. The utilisation of a given package of new technology may involve certain trade-offs. It may for example increase incomes and, at the same time, increase labour inputs and time constraints of certain household members. An early detection of such trade-offs and the design of corrective programme components



Source: Adapted from von Braun et al. (1989).

Figure 1. *Conceptual framework for the analysis of household-level effects of MODP technologies.*

are important in avoiding short-term adverse effects of technological change on small-scale farm households.

4.2 The potential contribution of intensified livestock production to food security

Technological progress in dairy production reduces unit production cost, resulting in a downward shift in the unit cost function and a shift to the right of the supply curve, i.e. the lower cost of production increases supply. The total economic welfare or economic surplus defined as the sum of the Marshallian consumers' and producers' surpluses invariably increases. The cost of developing crossbred cows technology in the study area was borne by the Ethiopian Government via the Ministry of Agriculture, FINNIDA and donors supporting ILRI's research agenda. The distribution of the welfare gains between consumers and producers depends on the price elasticities of supply and demand. Assuming a downward sloping demand curve for dairy products, consumers' welfare will increase via the consumption of larger quantities at lower prices. Producers also benefit if they are able to increase output or lower the cost sufficiently to compensate for more than the price decline. If the demand is elastic, so that the price elasticity is not very low, the total revenue from the sale of output increases more than the cost of production. This results in a net gain to producers. The welfare effects of intensified dairying in the highlands of Ethiopia are shown in Figure 2, in which the market supply and demand relationships for dairy products are analysed. The income elasticities for milk, meat and eggs for tropical Africa are estimated at 0.82, 0.98 and 1.10, respectively, compared with 0.22 for cereals (Jahnke 1982). D_hD_h represents the demand curve of producers for home consumption. D_mD_m represents the market demand for dairy products and the horizontal difference between D_mD_m and D_hD_h, at any given price, represents the quantity purchased by non-dairy farm households. The supply curves before and after the technological change are measured by S_0S_0 and S_1S_1, respectively. The shift in market supply moves market equilibrium from A to B. Consumers purchasing dairy products increase consumption from OQ_0 to OQ_1, as prices drop from OP_0 to OP_1. Consumer surplus increases by ABP_1P_0, of which P_0CGP_1 accrues to consumers in producers households and CABG to non-producer households. Producer surplus changes from S_0P_0A to S_1P_1B. The more price-elastic the aggregate demand curve, the larger the producers' surplus will be, due to the outward shift of the supply curve.

Improvements in livestock production in developing countries can contribute to food security in numerous ways. First, increased milk production and a steady flow of cash income from the daily sale of surplus milk and dairy products contribute to all dimensions of food security, including accessibility and stability. Besides increasing the availability of and accessibility to more and better quality foods through increased milk production and higher incomes, a steady flow of cash income from the daily sale of milk may contribute to the stability of consumption in smallholder intensified dairying households. Second, livestock production and processing enterprises are labour intensive, thus increased production implies higher employment. This can secure incomes and food entitlements for the rural poor. Third, cost saving technological change increases production and keeps livestock product prices down, enabling more people from lower income groups to have access to food of animal origin. Fourth, increased domestic

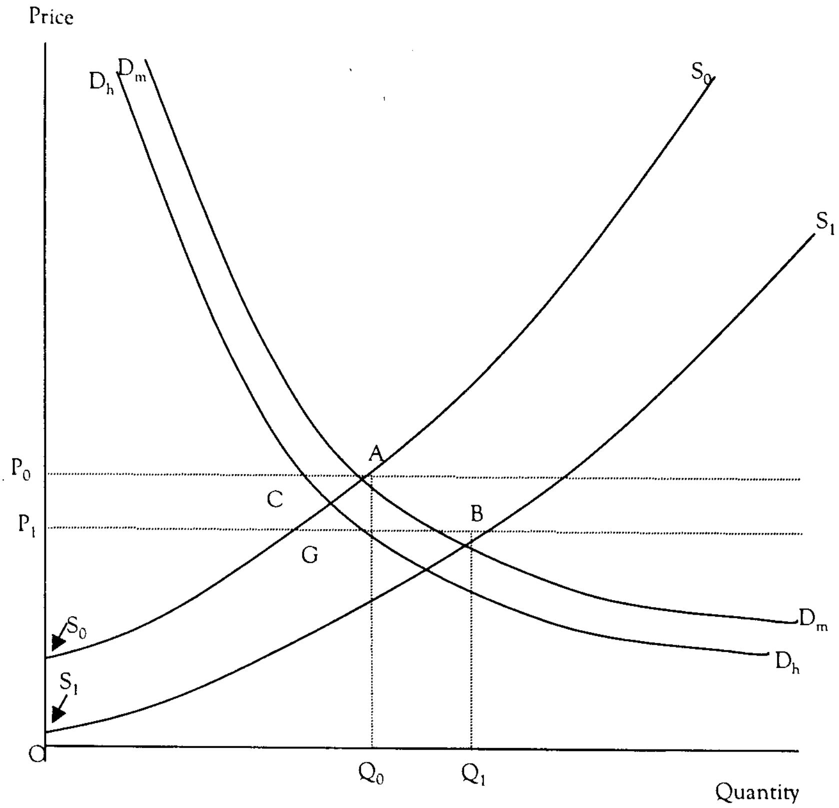


Figure 2. *The impact of technological change on the supply and demand of dairy products.*

production may reduce imports and save foreign exchange, which may then be used to invest in productive activities that can indirectly contribute to food security.

Intensified dairying is the most regular generator of income for small-scale farmers (Sansoucy et al. 1995). Dairy development has been shown to substantially raise milk production and household incomes in developing countries where development efforts are market-oriented and demand-driven (Walshe et al. 1991; Thomas-Slayter and Bhatt 1994; Pankhurst 1996; Shapiro et al. 1998). An FAO/UNDP dairy project in Burkina Faso assisted 100 families in increasing their monthly incomes by US$ 80, the equivalent of an extra labour unit per family (Ehui 1997). Incomes of farmers who use intensified technologies for the production of meat and milk have been shown to increase by 50–100% (Shapiro et al. 1995; Buta 1997). Evidence from the Ethiopian highlands shows per capita food availability to be 67.5% higher in households with crossbred cows than in those with traditional cattle (Shapiro 1994). Returns from market-oriented small ruminant activities in the Sahel have been found to be 24% higher than in traditional practices and capital returns to be more than 50% (Shapiro 1994).

The structural changes taking place in SSA are expected to bring about more technological changes in livestock production in the next decade. Besides population growth, urbanisation and rising incomes, recent currency devaluation and price liberalisation are additional factors pushing for intensification. Better integrated crop–livestock systems will need to be replaced by a more intensive and specialised crop and livestock system to obtain rapid growth rates and to respond to increasing demand for animal food products.

4.3 Theoretical framework

The agricultural household modelling approach was used to analyse the food security and marketed surplus outcomes of the new technologies. The agricultural household model providing a joint model of production and consumption decisions is a natural structure for the Ethiopian peri-urban semi-subsistence households. Its theoretical underpinnings are provided by the household economics literature, initiated by Becker (1965) by bringing the theory of the household into mainstream economics. In the literature, summarised in Haddad et al. (1997), the household is modelled either as a single unit in the unitary model or as a collection of entities in the collective models.

This section starts with the general theoretical structure for a small-scale farm household and then adapts it for the particular problem to be addressed in this research. The equations specified in this section provide the theoretical support for the empirical specifications of the following equations to be estimated: food consumption equations, calorie intake equations and marketable surplus equations. The resultant equations to be estimated are specified in Section 5.

4.3.1 Basic model

The agricultural household model, incorporating production and consumption decisions explained in this section forms the basic structure of the empirical equation specified in Section 3 and estimated in this paper.

Following Becker (1965), Singh et al. (1986) and Behrman and Deolalikar (1988), households obtain utility from the consumption of Z-goods specified as:

$$U = U(Z_1, Z_2, \ldots, Z_n) \qquad (1)$$

where the Zs are consumable goods. Assume for the moment that there are two sets of goods: calories (Z_1) and other n-1 consumable goods. The production functions for the Z-goods are:

$$Z_i = Z_i(X_m, X_a, X_S, F; R) \quad i=1,2,\ldots,n \qquad (2)$$

where X_m is market-purchased goods, X_a is agricultural staples produced by the households, X_s is leisure, F is family labour endowments and R, a non-choice vector of variables, represents individual and household characteristics, such as ages, years of education, household size, dependency ratio and other environmental variables. The household utility function can therefore be specified as:

$$U = U(Z_1(X_m, X_a, X_s, F; R), Z_2(X_m, X_a, X_S, F; R), \ldots, Z_n(X_m, X_a, X_s, F; R)) \quad (3)$$

The household picks the optimal consumption bundle, subject to its production technology:

$$Q = Q_a(A, L, V, K) \quad (4)$$

where Q_a is the household's production of staple food, A is land, L is total labour input, V is a vector of variable inputs (fertiliser etc.), K is a vector of capital (native oxen, CBC, farm implements).

The household also faces a budget constraint:

$$p_m X_m = p_a(Q_a - X_a) - w(L - F) + E \quad (5)$$

That is, given prices, p_m, the total market consumption, $p_m X_m$, cannot exceed the total income, that is the sum of non-labour income, E, labour earnings, w(L – F), and the value of food marketed surpluses, $p_a(Q_a - X_a)$. F is the family labour supply, such that (L–F) if positive it represents hired labour, and if negative it is off-farm labour supply. The household also faces a time constraint: that is the total time, T, available to the household cannot exceed the sum of time in leisure X_s and time working on-farm or off-farm, F:

$$T = F + X_s \quad (6)$$

Substituting the production constraint (4) for Q_a and incorporating the time constraint (6) into the budget constraint (5) for F, yields the following constraint:

$$p_m X_m + p_a X_a + w X_s = wT + \pi + E \quad (7)$$

where, $\pi = p_a Q_a(A, L, V, K) - wL$, measures farm profit. The left-hand side of (7) represents total household expenditures on purchases of market commodities ($p_m X_m$), the household's purchases of its own output ($p_a X_a$), and the household's purchase of its own leisure time (wX_s). The right-hand side represents the full income in which the value of the stock of time available to the household (wT), profit (π) and non-labour income (E) are explicitly recorded.

From equations (3) and (7), the household can choose (i) the consumption levels for the Z-goods through the consumption of X_m, X_a and X_s and (ii) the total labour input into agricultural production. The first order conditions (FOC) for maximising the choice variables are explored in Tangka (2001). FOC for labour can be solved for L, as a function of prices (p_a and w), the technological parameter(s) of the production function (K) and the fixed area of land (A).

$$L^* = L^*(w, p_a, K, A) \quad (8)$$

The value of the full income, when profits have been maximised through the appropriate choice of labour input, can be obtained by substituting L into the right-hand side of the full income constraint (7), which could then be re-written as:

$$p_m X_m + P_a X_a + wX_s = Y^* \qquad (9)$$

where Y^* is the value of full income associated with profit maximisation behaviour. Maximising the utility function (3) subject to (8) yields standard demand curves of the form:

$$X_j = X_j(p_m, p_a, w, Z_1, Z_2, \ldots, Z_n, Y^*; R) \qquad (10)$$

Demand depends on prices and incomes, as well as on the environmental characteristics of the households. In semi-subsistence agricultural households, income is determined by the households' production activities, implying that changes in factors influencing production, such as the introduction of new technology, changes Y, which in turn affects the consumption behaviour. Thus consumption behaviour depicted in (11)

$$X_j = X_j(p_m, p_a, w, Z_1, Z_2, \ldots, Z_n, Y^*(A, L, K, V); R) \qquad (11)$$

is not independent of production behaviour depicted in (4). Expressing this as an expenditure equation, we have:

$$p_j X_j = E(p_m, p_a, w, Y^*(A, L, K, V); R) \qquad (12)$$

where X_j demand is derived from the demand for the Z-goods. Thus demand equations for the Z-goods can be expressed as:

$$Z = Z_i(X_j(p_m, p_a, w, Y^*(A, L, K, V); R)) \qquad i = 1,2,\ldots,n \qquad (13)$$

Since production is not influenced by consumption choices, this form of the model is recursive.

Various elements of the basic model will be modified in the following sub-sections to address pertinent issues specific to the problem to be analysed. This includes the impact of intensified dairying and market-orientation of small farmers on food consumption, per capita calorie intake and food marketed surplus for the harvesting and planting seasons.

4.3.2 Basic model modification

Seasonality analysis

One interesting question is whether the utilisation of crossbred cows technology reduces consumption differences in the food deficit and food surplus periods, focusing specifically on calorie intake. During the planting season, calorie stress is thought to influence productivity (Behrman et al. 1997, p. 191). There are two significant implications of this approach. First, with food insecurity at the household level, production is argued to be dependent on calorie intake:

$$Q_1^p = Q_1^p(A^p, L_e^p(Z_1^p), V^p, K^p) \tag{14}$$

$$Q_1^h = Q_1^h(A^h, V^h, K^h, L_e^h, A^p, L_e^p, (Z_1^p), V^p, K^p) \tag{15}$$

where Z_1^p = calorie intake during the planting stage, $L_e^p(Z_1^p)$ is the efficiency unit of labour for the planting season. Since production is a function of calorie consumption during the planting season, the recursive nature of the model from production to consumption is lost.

Second, there are two separate calorie equations, one for the planting season (Z_1^p) and one for the harvest season (Z_1^h). The planting season is generally characterised as a stage of shortage with high food prices and a high cost of borrowing (Behrman et al. 1997, p. 191). The assumption that calories affect production follows from low levels of consumption adversely affecting labour input. Calorie consumption during the planting season is given as:

$$Z_1^p = Z_1^p(Y^p, p_m^p, p_a^p, w^p, R, G) \tag{16}$$

where G is the joint distribution of the stochastic variables that become known to the farmer at the beginning of the harvest period. This includes harvest stage wages and prices, the production shock and efficiency of the hired workers in the planting period (Behrman et al. 1997). Although calorie stress is unlikely to be a problem during the harvest season, the effects of calorie stress during the planting season are passed through to the harvest season consumption. The harvesting period consumption decision rule can be written as:

$$Z_1^h = Z_1^h(Y^h, p_m^h, p_a^h, w^h, Y^p, p_m^p, p_a^p, w^p, R, G, \varepsilon) \tag{17}$$

The harvest stage consumption differs from the planting stage consumption equation in that it incorporates planting stage wages (w^p), market good prices (p_m^p), prices of agricultural staples (p_a^p), income (Y^p) and the unanticipated component of income (the shock ε). Similar equations for the planting and harvesting stages can be specified for food consumption and labour allocation equations.

The above structure, i.e. specification of two calorie intake equations by season, is appropriate in the case of Ethiopia, given its transitory food insecurity problems and associated levels of calorie stress. An increased daily flow of cash income and milk production resulting from market-oriented intensified dairying has the potential of reducing seasonal calorie stress.

Commercialisation analysis

Households using dairy technology are expected to produce surplus food products, particularly milk, for sale to raise cash income that can be used to purchase other needed food items in an effort to become more food secure. The market surplus analysis focuses on the marketed outcomes of food (*FOODMA*) and explains it as an excess supply function.[5] It can be specified for the planting and harvesting seasons as a function of food production and food consumption variables for the respective seasons.

$$FOODMA^{p} = f(Y^{p}, P_{m}^{p}, P_{a}^{p}, w^{p}, A^{p}, K^{p}, R, G) \tag{18}$$

$$FOODMA^{h} = f(Y^{h}, p_{m}^{h}, p_{a}^{h}, w^{h}, A^{h}, K^{h}, Y^{p}, P_{m}^{p}, p_{a}^{p}, w^{p}, A^{p}, K^{p}, R, G, \varepsilon) \tag{19}$$

The dynamic and stochastic sequential production processes (planting and harvesting) imply that decision rules are fundamentally different for each season (Behrman et al. 1997). The two market surplus equations are therefore needed to test for differences in food marketed surplus and hence cash income for the harvesting and planting seasons. Food marketed surplus is expected to be smaller in the planting than the harvesting stages.

4.4 Empirical model and hypotheses

The food expenditure, calorie intake and marketed surplus equations derived in the previous section are being tested here to examine the effects of intensified dairying on food security and food marketed surplus. The models are specified and estimated for the whole sample and separately for each of the two groups with and without the improved cattle. The variables are defined in Table 1. The logic of the regression analysis in terms of food security is to move from household food consumption to household calorie intake as shown in Figure 1. At each link, the concern is how variables such as income, animal value, cropped land area, education and age of household head and distance to the market condition the degree to which the potentially beneficial effects of increased income are transmitted to food security.

4.4.1 Food consumption model

Food consumption = f (Household income, wife's income, land area, animal value, age and education of household head, household size, market distance, woreda, *season)* (20)

The propensity of poor farm households to spend incremental income on food is usually high. This is examined with the food consumption equation. The model is formulated, taking into account conventional approaches to demand analysis and the

5. If food production (equation 4) were to be estimated, marketable surplus would be identical to the difference between the value of food production and consumption.

Table 1. *Definition of variables used in the empirical analysis.*

Variables	Definitions
Value of food consumed	Household cash food expenditure plus value of food consumed from own production (Birr,[a] per adult equivalent)
Energy	Daily average household calorie intake (in calories per adult equivalent).[b] This includes all food, both from home production and purchases
Value of marketed foods	Household value of marketed foods (Birr). This includes cash income from sales of crops and dairy products
Land area	Cropped land (ha)
Animal value	Livestock value (Birr)
Age of HH head	Age of household head (years)
Household size	Number of household members in adult equivalents
Household income[b]	Composed of total farm and non-farm income, less variable cost. Farm income includes value of food from own production, revenues from sales of dairy and non-dairy farm products. Variable cost is the sum of expenditure on crops and animal feed inputs, animal feed, animal health and other services and land rental
Wife's income[c]	Household income handled by wife. This does not include value of food from own production
Distance to crop market	Round trip distance to the main market from each household (km)
Location	*Woreda* (1 = Wolmera, 0 = Addis Alem)
E1	Education level of household head (1 = read and write, 0 = otherwise). Illiteracy is the base level
E2	Education level of household head (1 = Elementary, 0 = otherwise). Illiteracy is the base level
E3	Education level of household head (1 = High school, 0 = otherwise). Illiteracy is the base level
Season	Zero–one dummies for each quarter of the year. Fourth quarter is the base level.

a. Birr is a unit of the local currency. The exchange rate at the time of the study was US$ 1 ≅ EB 7.5.

b. The food consumption tables compiled by the Ethiopian Health and Nutrition Research Institute were used to convert quantities of ingredients used in preparing food consumed during different meals to calories.

c. The natural log of these variables were not used because of negative income values for some households.

structural determinants of food consumption decisions in the households imposed by the local situation. Demand theory suggests that in semi-subsistence societies, food consumption is determined by income level and the market prices of the major traded staples. Income raises food consumption per adult equivalent. Price variables are not included in the model because of price invariability in the cross-sectional sample. Most farmers exchange in the same markets and face the same prices at a given time. Distance to the crop market and location are included to capture transaction costs that may differ among households. Distance to crop markets for each household and *woreda*, where the household is located, controls for variations in food consumption because some households reside nearer the crop market. It has been suggested that women spend more income on food (Kennedy and Cogill 1987; Quisumbing et al. 1995), it is therefore hypothesised that incomes in the hands of women have positive food consumption effects. The variable 'Household income handled by wife' tests for the effects of the new technologies in dairy production on the women's spending on food, beyond its income effect, which is controlled by the total household income.

Food consumption is further hypothesised to be determined by household size and demographic variables (age and educational level of household head). These variables are important for their income earning and expenditure potentials. The household size also controls scale effects; large households tend to spend less per adult equivalent on food. The age and education of the household head are expected to contribute to greater food consumption. Literate household heads have better knowledge through their wider exposure to information. Agricultural production inputs are expected to affect outputs, incomes and hence food consumption, positively. The production inputs in the model include cultivated land area and capital stock measured by animal value.

4.4.2 Calorie intake model

Calorie intake = f (Value of food consumed, land area, animal value, age and education of household head, household size, market distance, woreda, *season)* (21)

This equation relates the effects of food consumption to the calorie intake per adult equivalent. Numerous factors, in addition to food consumption per adult equivalent, determine the calorie intake. It is hypothesised that higher food consumption has a positive calorie intake effect, because food purchases and higher own-farm production increase availability of calories. Likewise, cultivated land area, animal value, age of household head and educational level are expected to affect calorie intake positively. Household size is expected to have a negative effect on calorie intake. Distance to the crop market and location of the household are associated with higher transaction cost and therefore expected to have a negative effect on calorie intake.

Behrman et al. (1997) gave particular attention to the importance of seasonal variation in consumption and production. They argued that during the planting season a shortage of calories would result in reduced production for the following season. In this case, households with the improved cattle and potential for continuing milk production with potential cash sales should face less volatility over the year in calorie consumption, than households with traditional, lower productive cattle. Seasonality is addressed by including dummy variables for each quarter of the year in the calorie intake equation.

4.4.3 Marketed surplus model

Marketed surplus = f (Household income, wife's income, land area, animal value, age and education of household head, household size, market distance, woreda, *season)* *(22)*

The analysis of the demand-side effect of the new technologies is as important as the supply-side effects. The changes in food marketed surplus are due to a combination of technological change and commercialisation effects. Increased outputs achieved through technological change in dairy production do not translate into a straightforward expansion in marketed surplus. Substitution effects in production and consumption may either increase or decrease the marketed surplus of output growth resulting from new technology. Technological change in the study area increases milk production and dairy income but may affect crop production, if the household changes its resource allocation to produce additional cattle feed and forage. As a consequence, households with dairy cows may sell some of the dairy products to purchase cereals.

The model is specified with the following hypotheses in mind: increased income from dairying with crossbred cows increases the supply of crops, livestock and livestock products via increased purchases of inputs. As noted above, prices are unavailable in the data and are expected to be constant across the sample of households. The distance to crop markets for each household and the location of households are again used to control for differing transportation (transaction) costs. More animals and land area represent greater productive capacity and are therefore hypothesised to increase marketed surplus. The age and literacy of household heads are expected to contribute to greater production and marketed surplus. Older and more literate household heads may have more farming experience and better farming knowledge, through their wider exposure to information via extension agents, for example.

5 Data collection and descriptive analysis

The optimal strategy in planning the research would have been to survey semi-subsistence households, before and at several stages after, the introduction of the intensified dairy production system. The cost and length of time involved in undertaking such surveys precluded pursuing this optimal strategy. The alternative strategy followed consisted of cross-sectional and time series comparisons of two groups, one which had switched to intensified dairy production and the other which had remained in traditional animal husbandry. This strategy required careful selection of two groups with similar resource bases.

The researcher, in collaboration with International Livestock Research Institute (ILRI) in 1999 collected detailed socio-economic and demographic data used in this study at the household level and individual levels. Panel data are available for 56 households: 27 with improved dairying practices and 29 using traditional dairying methods. Of the 56 households surveyed, only two were female headed. Information was obtained on income, expenditure, production, consumption, input use, resource allocation (land, labour) and demographic variables such as age, educational level and household size.

5.1 Data collection method

The questionnaires used to collect data from the sampled households are (1) socio-economic, (2) food intake, (3) baseline, (4) land measurement, (5) sample yields and (6) distance and time from households to main crop market.

5.1.1 Socio-economic questionnaire

This questionnaire was used to collect data on incomes and expenditures on food and non-food items, production and distribution of dairy products, and labour allocation to dairying activities. Most of the farmers were visited once a week and information was obtained on a daily recall basis. The household member who went to the market (wife, husband or child) provided information on what was bought and sold. Information on food consumption and quantities of food consumed from own production was mostly given by the wife whereas that on farm income and expenditure, animal feed and other farm inputs, animal and crop sales (in large quantities) was provided by the husband on many occasions. The food and non-food items listed in the questionnaires were sometimes read to facilitate recall. Children attending school assisted in recording what was bought and sold in their households, the quantities of food items eaten from own production and the production and distribution of dairy products. The households that did not have children and had trouble remembering the above information were visited more than once a week. Quantities and prices reported in local units were converted to standardised units ('Système International' SI-International System units) before calculation of incomes and expenditures. Data for labour allocation on the dairy operation were recorded once every two weeks. These data were collected on holidays, when farmers do not undertake crop activities, but can perform dairy operations. Farmers were observed for 12 hours and information recorded on the start and finish time of each dairy operation.

5.1.2 Food intake questionnaire

This questionnaire was used to obtain information from women who normally prepare food on (1) the types and quantities of ingredients, in standardised units, used to prepare food eaten in the household during the last 24 hours, (2) the ages and number of people, including guests who consumed the meals and (3) the proportion of meals left over. Care was taken to collect information on consumption of snack foods, especially the energy dense ones such as roasted and boiled cereals, *kolo* and *nifro*, respectively. This information was obtained every month. In the study area, there is a large day-to-day variation in food consumption, depending on whether it is a fasting or non-fasting day. Animals and dairy products are not consumed during fasting days. There were 139 fasting days spread throughout the year in the study area, populated primarily by Orthodox Christians. In order to capture a more typical food intake behaviour, food consumption information was collected from six fasting and six non-fasting days. The food conversion tables prepared by the Ethiopian Health and Nutrition Research Institute were used to convert food ingredients, used in the preparation of different meals, into calories.

5.1.3 Baseline questionnaire

This questionnaire was administered once during the year and was used to obtain (a) demographic information on each household member, such as names, relation to household head, marital status, age, sex, education and main occupation during the wet and dry seasons, and (b) livestock type, age (months), breed, origin and value in Birr. The husband, wife or both gave this information.

5.1.4 Land measurements questionnaire

This questionnaire was administered once during the year to record the total land holding (cropped, fallow and pasture) area of the household. The area was measured by assigning numbers to fields and plot, and taking measurement of each plot in each field with a measuring tape. The number of plots corresponded to the different crops grown in a given field. The number of fields matched the different parcels of land the household owned in different locations. The area of the land was calculated by summing the areas of the triangles in each plot.

5.1.5 Sample yield questionnaire

Samples were taken from five different spots in each plot using a one square metre quadrant before farmers began harvesting and after the total area covered by each crop had been recorded. The crops were harvested using a sickle and collected in fertiliser bags, which were labelled according to the plot and field numbers, crop type and sampling date. The harvested crops were threshed carefully on dry cattle skin, *kurbet*, winnowed and the grain yield recorded. Based on the sample yields and the total cropped area, the amounts of different grains harvested by each farm household were estimated.

5.1.6 Market distance questionnaire

This questionnaire was completed once during the survey period. Information was collected on the name of the market, transportation system used (trekking, mule/horse or vehicle), round trip distance in kilometres and time in minutes.

Most studies evaluating the effects of increased income on nutritional status only collect food and non-food consumption data, because of the expense involved in collecting income and food intake information. Many researchers also feel that total expenditure, the sum of food and non-food expenditures, a proxy for income, is a better measure for 'the permanent income' than income (Bouis and Haddad 1990). Quantities of particular foods included in the food consumption questionnaire give an estimate of calorie availability. This differs from calorie intake, collected from a 24-hour food intake recall, by the amount of food purchased, but not eaten, by household members. This could be due to food wasted in storage or during preparation, and food given out or fed to guests or beggars.

Bouis and Haddad (1990) discussed several questions that could be raised regarding the collection of income, expenditure and food intake data, addressing which are more reliable and how these variables could be related empirically. Two key points are noted. First, any random errors in measuring food purchases are transmitted both to calorie availability and to total expenditures, leading to correlation among measurement errors for these three variables and the error term. This results in biased coefficients on the explanatory variables, if any pair of these variables (one as the dependent variable) is used in the regression analysis with ordinary least squares (Bouis and Haddad 1990). Second, systematic underestimation of meals served to non-family members may be positively correlated with income. This can result in an overestimation of family food consumption for high-income groups and of the relationship between calories and income, if the analysis is based on calories available data. Because of the difference between calorie availability and calorie intake and the possibility of collecting income data, this study used income and calorie intake data in the regression analysis.

5.2 Descriptive analysis

One method to test the impact of MODP technologies is through statistical comparison of households with and without CBC. The descriptive analysis is based on means and standard deviations (SD) computed from the data sets. Independent sample t-tests are conducted to test the differences between CBC and LBC groups. Comparison in resource allocation, income distribution and expenditure patterns of adult males and females were also carried out. The comparisons between the groups and gender were made to provide the basis for the more comprehensive assessment (via econometric analysis) of the impact of market-oriented dairying with crossbred cows on food security and food marketed surplus of participating households.

5.2.1 Value of food consumption impacts

In the CBC and LBC households, 67 and 66%, respectively, of the value of total food consumed is home grown. The difference in the values of food from own production and purchases from the market reflects the semi-subsistence characteristic of the households.

Given home-produced food in semi-subsistence agriculture, food expenditure can change as a consequence of higher and more readily available cash income from dairy operation as noted with other examples of agricultural commercialisation (Kennedy and Cogill 1987). For the households considered in this study, average monthly per adult equivalent food expenditure is 36% higher for CBC compared with LBC households and is statistically significant at the 1% level (Table 2).

Table 2. *Food expenditures and value of food from own production, Birr per month.*

	All households		CBC households		LBC households	
Variables	Mean	SD	Mean	SD	Mean	SD
Women's food expenditures*	57.2	52.11	65.03	51.2	50.1	51.98
Husband's food expenditures	19.15	34.34	19.27	37.28	19.05	31.49
Total household food expenditure*	76.35	54.51	84.3	57.4	69.05	50.79
Food expenditure adult equivalent*	13.88	10.48	16.13	11.81	11.84	8.63
Food consumption from own production*	153.62	137.99	172	168	136.8	100.4

* Statistically significant differences in means between the groups at the 0.01 level using a t-test.

Earlier studies reviewed by Tangka et al. (2000) show that in many societies the wife and husband have different responsibilities, based on gender division of labour, to meet family needs and each family member uses mainly the income they earn to achieve their given tasks. This is not true in all cases, as income may be earned in one way and expenditure done in another way. Women tend to spend more on food than men. For example, in a study of the Beti in Cameroon, Guyer (1980 and 1988) reported that women contribute two-thirds of total expenses on food and routine household supplies. Analogous findings are demonstrated in more recent studies, such as Kennedy and Peters (1992) who illustrate that female-headed households in Kenya and Malawi spend a larger proportion of their incomes on food. This may be partly because female-headed households are poorer and generally spend more on basic needs like food.

An interesting question is whether intensified dairying changes the way income is handled by husbands and wives and if these changes adversely affect food expenditures—traditionally a woman's responsibility. According to gender division of labour within rural Ethiopia, women are responsible for buying and selling certain food items (vegetables, butter and cheese, small quantities of cereals etc.) and for preparing food, among other household reproductive chores. Table 2 shows that women in both CBC and LBC households are purchasing more food than men. Women make over 70% of food expenditures in both groups. With the introduction of MODP technologies, the purchasing of food by women in CBC households increased by 30%, while men in CBC households only increased their purchases of food by about 1%. Increased food expenditure by women in CBC households implies that women's defined functions have not changed but have been made easier, i.e. due to higher income (shown in Table 4) from improved dairying, they are able to spend more money on culturally defined functions, such as purchasing food.

5.2.2 Calorie intake impacts

Several studies have documented that technological change and commercialisation of smallholder production improve the level of food consumption, hence the calorie intake of participating households (von Braun and Kennedy 1994). Changes in food consumption are generally associated with more readily available cash income. Meanwhile, increased commercialisation may result in greater self-sufficiency via increased productivity of the land and labour inputs allocated to the commercial activity and changes in cropping patterns (von Braun 1995). With a higher income, a substitution of cheap calories for more expensive calories can take place and consequently, diets gain not only in quantity, but also in quality and diversity. Consumption changes affected by technological change and commercialisation have been attributed to increased income rather than to higher food availability (Alderman 1987; Binswanger and von Braun 1991).

The recommended minimum daily calorie intake per adult equivalent for Ethiopia is 2339 (Cleaver and Donovan 1995). Household members in CBC and LBC households are meeting 94 and 73% of this requirement, respectively. As depicted in Table 3, CBC households consume 30% more calories per adult equivalent person than LBC households. The comparison in Table 3 show differences that are both nutritionally and statistically significant between the CBC and LBC groups.

Table 3. *Calorie intake per adult equivalent and per capita.*

	All households		CBC households		LBC households	
Variables	Mean	SD	Mean	SD	Mean	SD
Calories per adult equivalent person (daily)*	1941.8	680.9	2210	713	1701	549
Calories per capita (daily)*	1588.4	487.9	1793	512.5	1404	380.6

* Statistically significant differences in means between the groups at the 0.01 level using a t-test.

Figure 3 shows the seasonal variation in calorie intake per adult equivalent between the two groups. The calorie intake patterns are surprisingly similar for the CBC and the LBC groups, i.e. high during and after harvest (December to June) and low just before harvesting (October and November). The primary difference is that CBC households (the higher income group) consume approximately 30% more calories per adult equivalent than the LBC households (the lower income group) throughout the year. The results suggest substantial and significant food security improvements with the MODP technologies.

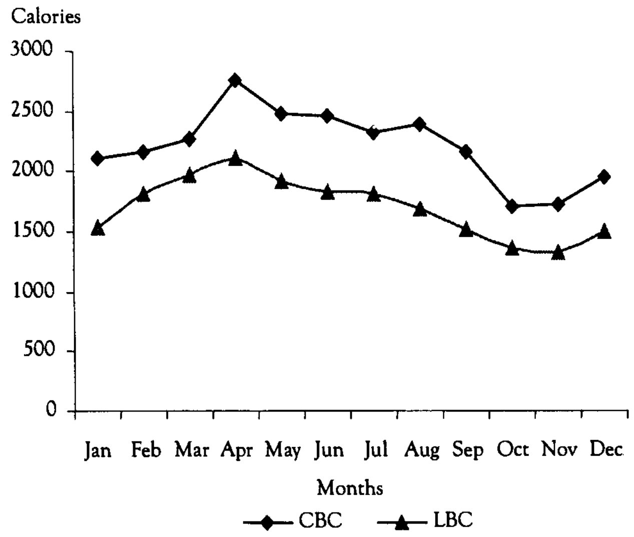


Figure 3. *Seasonal variation in calorie intake/adult equivalent per day, 1999.*

5.2.3 Income impacts

Several studies in East Africa and India have shown significant increases in the cash incomes of CBC households as a result of higher milk production and increased commercialisation of dairy products (Kennedy and Cogill 1987; Walshe et al. 1991; Shapiro et al. 1998). Similar results were shown for this study (Table 4). Household and dairy cash incomes were significantly higher in the households that keep CBC (208.37 and 158.85 Ethiopian birr per month, respectively) than in the households that keep LBC (162.58 and 13.61 Ethiopian birr per month, respectively). The difference is attributed mainly to the sales of liquid milk. Disaggregating cash incomes into dairy, non-dairy farm and off-farm income sources, the monthly dairy income of CBC farmers is 11.67 times higher than that of farmers using traditional production methods.

An important question is whether the introduction of intensified dairying makes women better or worse off. Under traditional dairy production practices, women retain 99.9% of the dairy incomes (Table 4). Whalen (1983) reported that under traditional

Table 4. *Monthly household disposable and cash incomes, Birr per month.*

Income types	All households		CBC households		LBC households	
	Mean	SD	Mean	SD	Mean	SD
Household disposable income*	184.31	277.57	208.4	327.6	162.6	221.2
Sources of cash income						
1. Dairy sales**	82.54	152.14	158.9	189.6	13.61	40.47
Total						
Husband**	30.71	114.75	64.68	160	0.02	0.38
Wife**	51.83	109.87	94.17	142.4	13.59	40.09
Milk						
Husband**	27.39	110.51	57.7	155	0	0
Wife**	6.16	57.11	32.54	376.5	2.23	22.18
2. Non-dairy farm income	128.54	210.0	118.0	221.6	138.1	198.8
Husband	76.62	198.18	77.03	214.5	76.25	182.4
Wife**	51.95	77.33	40.98	60.08	61.86	89.04
3. Off-farm income	50.14	140.72	49.45	167.7	50.75	111.1
Husband	29.61	117.23	31.24	152.4	28.14	72.24
Wife	20.52	76.08	18.21	67.08	22.61	88.58

* Statistically significant differences in means between the groups at the 0.05 level.
** Statistically significant differences in means between the groups at the 0.01 level using the t-test.

dairy practices, most of the milk yield is processed into butter and sold in the local market. Women exclusively undertake these activities. Women use the proceeds to purchase household consumption items, primarily food. The husband's dairy incomes increased more with intensified dairying (Table 4). Note, however, that the primary purchaser, the Dairy Development Enterprise, requires the household heads, mostly men, to register as the seller and collect the cash income. Their monthly cash income from fresh milk sales was 58 Birr compared with zero for the LBC owners. The milk incomes of women in CBC households were 15 times those of women in LBC households. In addition to increases, mainly from the marketing of milk, women in CBC households gain additional dairy income through sales of butter and cheese, i.e. the higher milk output allowed women to process more milk, while some was sold liquid for cash. While women in LBC households realised a large share of the dairy income relative to their husbands because of the defined division of work, women in CBC households earned nearly 7 times more dairy income than women in LBC households. This is due to the same division of work but with greater opportunities resulting from increased output. Women in CBC households realised about 59% of total dairy income, mostly from the sale of milk and milk products. Men sell mainly liquid milk.

Table 4 indicates that the average monthly non-dairy farm and off-farm incomes between the CBC households and LBC households were not statistically different, with the exception of women's non-farm incomes. This suggests that the higher household incomes occurring in CBC households were attributed mainly to dairy sales, as a consequence of intensified dairying. In CBC households, men earn 65 and 63% of non-dairy farm and off-farm incomes, respectively. While in LBC households, men earned 55% of both non-dairy and off-farm incomes (Table 4 and Figure 4). Non-farm dairy incomes were obtained from land rental, animal service (bull service) and sale of crops, live animals, cow dung, animal skins and animal feed. Off-farm income sources included weaving, handicraft, house rent etc.

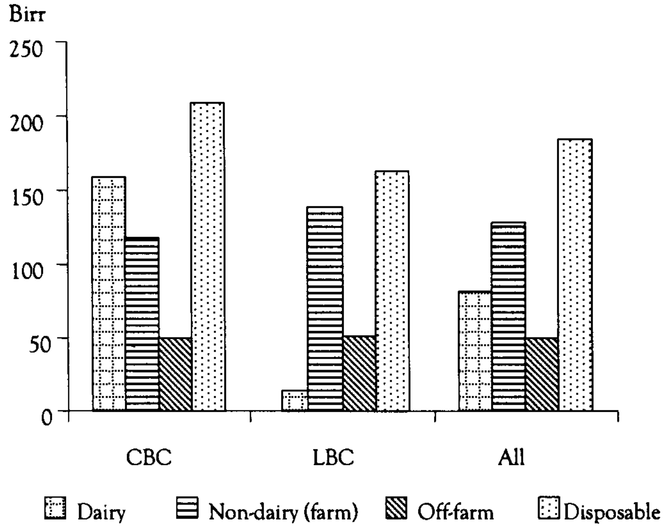


Figure 4. *Average monthly household cash and disposable incomes.*

5.3.4 Non-food expenditure impacts

Expenditures discussed in this section are cash expenditures on farm inputs (fertiliser, herbicides, insecticides, seeds etc.), animal feed, animals, animal health, land rental and non-farm commodities. Expenditure levels are expected to change as a result of the higher and more readily available cash income from intensified dairy operations. Other examples of agricultural commercialisation have shown the same impact (Kennedy and Cogill 1987; von Braun 1995). Similar findings were shown for this study (Table 5): households with CBC had higher monthly average non-food expenditures compared with LBC households. In addition, the expenditure levels of men were higher than those of women for all non-food categories. The differences in levels of expenditures between men in the CBC and LBC households were statistically significant, except for animals and land rental. Men in households with CBC purchased significantly more animal feed and animal health services, it can thus be concluded that while women spent increased incomes on food, men used increased income for farm investment and non-farm expenditures.

Table 5. *Monthly average non-food expenditures, Birr per month.*

	CBC households		LBC households	
Expenditures	Mean	SD	Mean	SD
Farm inputs				
Husband*	29.86	105.91	14.45	44.87
Wife	3.39	28.34	1.06	9.41
Animal feed				
Husband**	32.72	56.33	1.14	6.53
Wife**	5.35	13.88	0.26	1.9
Animals				
Husband	37.06	170.93	18.03	109.29
Wife	2.44	28.23	2.75	49.28
Animal health				
Husband**	2.25	6.1	0.58	3.29
Wife	0.19	1.38	0.07	0.64
Land rental				
Husband	4.67	29.65	1.55	18.93
Wife	0	0	0	0
Non-food, non-farm				
Husband**	52.21	135.79	33.69	73.69
Wife**	36.3	74.46	25.74	45.72

* Statistically significant differences in means between the groups at the 0.05 level.

** Statistically significant differences in means between the groups at the 0.01 level using the t-test.

5.3.5 Food marketed surplus impacts

The average monthly values of marketed foods such as crops, milk, butter, cheese, live animals and other livestock products were EB 209, EB 277 and EB 148, for the whole sample, CBC and LBC groups, respectively. The means for the CBC and LBC were statistically different at the 1% level of significance (Table 6). The difference is mainly accounted for by the higher sales of dairy products by the CBC households.

5.3.6 Cropped area and animal value impacts

Households keeping CBC cultivated about 17% more land than households with LBC (Table 7). A possible explanation for the difference is that although land was equally distributed on a per capita basis by the government, under its land reform policy, the secure the necessary inputs (oxen, labour, fertiliser, herbicides and seeds) to cultivate more land.

Table 6. *Food marketed surplus.*

	All households		CBC households		LBC households	
Variable	Mean	SD	Mean	SD	Mean	SD
Value of surplus food marketed (Birr/month)*	209.04	254.68	276.56	285.69	148.1	205.1

* Statistically significant differences in means between the groups at the 0.01 level using a t-test.

Table 7. *Cropped area and animal value.*

	All households		CBC households		LBC households	
Variables	Mean	SD	Mean	SD	Mean	SD
Cropped area (ha)	2.4	1.03	2.57	1.06	2.2	0.97
Animal value (Birr)*	5732.8	3768.6	7843	4135	3826.8	2039.4
Herd size (TLUs)[a]	7.9	4.2	9.06	4.4	6.9	3.8

a. TLU = tropical livestock units. See Jahnke (1982) for conversion of animal head counts to TLU.
* Statistically significant differences in means between the groups at the 0.01 level using a t-test.

The animal value in CBC households was twice that of LBC households (Table 7). Improved breeds were more expensive than indigenous cattle and households keeping CBC have larger herd sizes. Although households using MODP technologies were expected to replace draft LBC animals with CBC, most of the CBC households did not do so. The crossbred cows were mainly used for dairy production, while the local cattle were used as the source of draft power.

5.3.7 Demographic and other household characteristics

Table 8 shows a summary of the demographics and other characteristics of the households in Holetta. Household size averaged 6.03 adult equivalents, with no statistically significant differences between the CBC and LBC households. Likewise, there were no differences between the ages and educational levels of the household heads. The average age of the household head was 46.25 years. Households with CBC and LBC were located at equal average distances from the main crop market and were equally distributed in the two *woredas* surveyed.

Table 8. *Demographic and other household characteristics.*

	All households		CBC households		LBC households	
Characteristics	Mean	SD	Mean	SD	Mean	SD
Household size (adult equivalent)	6.03	2.15	5.86	2.43	6.19	1.87
Age of household head (years)	46.25	15.24	45.1	15.2	47.32	15.48
Round trip distance to the main crop market (km)	11.17	6.27	11.0	6.73	11.33	5.94

6 Econometric analysis, results and interpretation

6.1 Specification test

The literature on farm models, such as Singh et al. (1986) and Behrman et al. (1997) argues that if markets are incomplete or if labour productivity depends on consumption, the consumption and production decisions of farm households are not separable and recursive. Kumar (1994) indicates that this is because food consumption is part of the farm household's utility function, given by choices made in the allocation of both income and time and subject to a combination of the production function, time and budgetary constraints. Therefore income is correlated with the permanent component of the error term (fixed effect). Hence, household incomes cannot be treated as exogenous in the food consumption and marketed surplus equations. Behrman et al. (1997, p. 195) further suggest that income is correlated with the permanent component (fixed effects), time-invariant characteristics of the household, such as land quality, farming ability and preferences that are not measured in the data.

Hausman (1978) developed a two-step procedure for testing the correlation between individual effects and explanatory variables. The test procedure can be outlined using the food consumption equation, where it is necessary to test for the correlation between income and the individual effects (α_i). The first step is to regress total household income on all other explanatory variables of the equation (presumed not to be correlated with the individual effects) plus at least one additional identifying variable. Total expenditure was used for the additional identifying variable. The second step involves regressing the food consumption equation as originally specified, but also including predicted household income obtained from step one as an explanatory variable. If the coefficient on predicted household income is significantly different from zero, then the null hypothesis of no correlation between the individual effects and total household income is rejected.

The Hausman test rejected the null hypothesis. The results of the Hausman tests for the various equations are presented in Table 9. The t-tests show that the coefficients of the predicted household income in the food consumption and marketed surplus equations and that of the predicted food consumption in the calorie intake equation were all statistically significant.

6.2 Estimation technique

The common method used to purge the estimates of potential bias arising from the endogeneity of some of the explanatory variables in the sample is the 'within-groups' or 'fixed effects' estimator from the analysis of covariance. This involves elimination of the individual effects in the sample, by transforming the data into deviations from individual means and performing least squares. The OLS (ordinary least squares) estimates from

Table 9. *Regression results for the Hausman test (step 2).*

	Equations					
	Food consumption		Calorie intake		Marketed surplus	
Variables	Coefficients	Standard errors	Coefficients	Standard errors	Coefficients	Standard errors
Household income	0.0445[a]	0.0042			0.386[a]	0.04
Household size	-31.74[a]	3.357	-93.04	39.9	-272.2[a]	31.85
Household head age	0.498	0.2603	-5.408	2.622	4.62	2.469
Land area	-10.53	6.579	-138.9[a]	43.01	-461.1[a]	62.39
Animal value	-0.0068[a]	0.0028	0.0380[a]	0.016	-0.1680[a]	0.026
E1 (1 = read and write, 0 = otherwise)[b]	8.081	8.475	156.0	85.61	401.8[a]	80.38
E2 (1 = elementary level, 0 = otherwise)[b]	-42.69[a]	12.89	82.94	94.31	-774.5[a]	122.2
E3 (1 = high school, 0 = otherwise)[b]	-13.39	10.93	-2.079	116.5	-460.9[a]	103.7
Wife's income	-0.1439[a]	0.041			-2.975[a]	0.386
Crop market distance	-3.852[a]	1.322	2.326	6.337	-116.2[a]	12.54
Woreda (0-1 dummy variable)	42.99[a]	15.61	375.0[a]	90.92	1133.0[a]	148.1
Value of food consumption			-1.498[a]	0.6344		
First quarter dummy	-76.04[a]	25.55	246.2[a]	109.8	-1891.0[a]	242.3
Second quarter dummy	-84.58[a]	27.94	523.4[a]	110.1	-2116.0[a]	264.9
Third quarter dummy	-14.97[a]	15.71	226.3	129.9	-1183.0[a]	148.9
Predicted household income	0.2633[a]	0.0688	5.210[a]	2.048	5.549[a]	0.652
Predicted value of food consumed			4.504[a]	2.213		
Constant	176.4	22.27	20,445.0	337.7	1575.0	211.3
N	224.0		224.0		224.0	
R^2	0.711		0.5619		0.7172	

a. Significant at the 0.05 level.
b. E1, E2, E3 are dummy variables representing the education level of the household head. Illiteracy is the base level.

the transformed data have two significant limitations: (a) the data transformation eliminates all time-invariant variables, so their coefficients (γ) cannot be estimated, and (b) the within-group estimator is not fully efficient, since it overlooks variation across individuals in the sample. Another approach is to find instruments for the X_{it} and Z_i which are uncorrelated with α_i. The difficulty is in finding the appropriate instruments, excluded from equation (20, 21 and 22) and which are uncorrelated with α_i. This approach, however, ignores the time-invariant characteristic of the latent effect, α_i.

The instrumental variable technique for panel data developed by Hausman and Taylor (1981)–hereafter HT–were used to obtain consistent estimates of all parameters in the presence of correlation between individual household effects and a subset of the explanatory variables. The technique depends on a correct partitioning of the explanatory variables into time-varying and time-invariant variables that are correlated and those that are uncorrelated with the unobserved household-specific effect. The HT estimator uses assumptions about which explanatory variables are uncorrelated with the individual effects. The condition for identification using the HT technique is met, i.e. there are at least as many time-varying variables, not correlated with the household effect, as time-invariant variables, correlated with the household effect. Thus the HT estimator is consistent. Efficiency gains are derived from the use of each exogenous time varying explanatory variable as two instruments: first as means and second as deviations from the means. The HT estimator represents a distinct improvement over the within estimator, since more efficient estimates of β and consistent estimates of γ are possible. The Wald test was performed for parameter equality in the crossbred cattle and control groups.

6.3 Results and interpretation

6.3.1 The effect of MODP technologies on food consumption

The estimated food consumption equation regression results presented in Table 10 relate to equation (20). A first question of interest is whether or not the response of food consumption to changes in the explanatory variables was significantly different between the CBC and the LBC households. The Wald statistic for equality of the parameters is:

$$W = (\hat{\beta}_{CBC} - \hat{\beta}_{LBC}) \left[(Cov(\hat{\beta}_{CBC}) + Cov(\hat{\beta}_{LBC}) \right]^{-1} (\hat{\beta}_{CBC} - \hat{\beta}_{LBC}) \qquad (23)$$

where $\hat{\beta}$ and Cov are parameter estimates and covariance matrices from the CBC and LBC equations, respectively. The Wald statistic, W, distributed as χ^2_{15} under the H_0, has a value of 16.56. Since the critical value for the χ^2_{15} is 22.3 at the 10% level, the parameters for the food consumption equation explanatory variables are not significantly different for the CBC and LBC groups. Given the result of the Wald test, the interpretation of the empirical results of the impact of MODP technologies on food consumption are based solely on the combined results.

The coefficient of total household income is positive and significant so that increasing household income increases expenditures on food consumption. The marginal propensity to spend on food is 0.034. The corresponding food consumption elasticity with respect to income, calculated at the means, is 0.29. With a 100% increase in income, food consumption increases by 29%. Although this estimate is positive and significant, it is somewhat smaller than one might expect and is smaller than estimates closer to unity, reported for other African studies in The Gambia (von Braun et al. 1989) and in Nigeria and Sudan (Alderman 1987). Among the differences between this study

Table 10. *Food consumption equation.*

Variables	All households GLS*	All households HT**	CBC households GLS	CBC households HT	LBC households GLS	LBC households HT
Constant	123.8	122.57	170.663	171.41	99.8698	98.02
	(-21.1)	(-22.873)	(-55.475)	(-59.802)	(-20.128)	(-15.934)
Household income	0.042	0.03407	0.0361	0.0286	0.0498	0.0466
	(0.0043)[a]	(0.0049)[a]	(0.0063)[a]	(0.0069)[a]	(0.0063)[a]	(0.0083)[a]
Animal value	0.004	0.00384	0.0024	0.0024	0.0043	0.0039
	(0.0010)[a]	(0.0011)[a]	(-0.0025)	(-0.0027)	(0.0019)[a]	(0.0016)[a]
Cultivated land area	11.7918	12.382	15.5163	17.109	4.9849	5.9725
	(3.6987)[a]	(4.019)[a]	(7.089)[a]	(7.6865)[a]	(-4.539)	(-3.6907)
Household size	-19.7826	-19.402	-19.867	-19.161	-14.524	-14.650
	(1.6603)[a]	(1.8066)[a]	(3.349)[a]	(3.6301)[a]	(2.204)[a]	(1.7573)[a]
Household head age	-0.0155	-03123	-0.3536	-0.377	-0.1128	-0.1023
	(-0.276)	(-0.2998)	(-0.6809)	(-0.7363)	(-0.2826)	(-0.217)
E1 (1 = read and write, 0 = otherwise)[b]	-9.0891	-9.533	-29.9799	-33.860	3.2868	3.7342
	(-8.817)	(-9.5907)	(-21.4434)	(-23.25)	(-9.867)	(-7.6601)
E2 (1 = elementary, 0 = otherwise)[b]	-3.5982	-2.3571	-22.8493	-24.658	-0.6355	-0.4974
	(-9.92)	(-10.793)	(-26.0953)	(-28.252)	(-9.0467)	(-7.753)
E3 (1 = high school, 0 = otherswise)[b]	5.01	5.6003	-26.6935	-29.064	17.9226	17.627
	(-12.12)	(-13.182)	(-32.56)	(-35.248)	(-11.326)	(8.7711)[a]
Crop market distance	0.757	0.8787	-0.2917	-0.2890	1.1493	1.328
	(-0.661)	(-0.7178)	(-1.4645)	(-1.5822)	(-0.7162)	(0.5900)[a]
Wife's income	0.008	0.0114	0.0071	0.0101	-0.00348	0.0046
	(-0.008)	(-0.0085)	(-0.0124)	(-0.0128)	(-0.0129)	(-0.0139)
Location	-9.8645	-11.365	-8.315	-9.9652	-8.2626	-9.2469
	(-9.097)	(-9.8968)	(-20.404)	(-22.113)	(-8.6853)	(-6.7624)
First quarter dummy[c]	19.76	22.75	29.4567	32.115	10.7614	11.243
	(6.4417)[a]	(6.4124)[a]	(11.026)[a]	(10.847)[a]	-6.307	-7.7574
Second quarter dummy	20.56	23.771	32.0294	36.648	12.2578	12.391
	(6.4549)[a]	(6.4363)[a]	(11.500)[a]	(11.426)[a]	(5.963)[a]	-7.3203
Third quarter dummy	40.39	42.094	48.187	49.953	33.3744	33.622
	(6.291)[a]	(6.2241)[a]	(10.898)[a]	(10.694)[a]	(5.939)[a]	(7.3052)[a]
	N = 56	N = 56	N = 27	N = 27	N = 29	N = 29
	T = 4	T = 4	T = 4	T = 4	T = 4	T = 4
Food consumption elasticity with respect to income		0.29		0.24		0.41
Food consumption elasticity with respect to land		0.26		0.33		0.14
Food consumption elasticity with respect to animal value		0.18		0.14		0.15

Notes: The dependent variable is value of food consumed per adult equivalent.
Figures in parentheses are standard errors.

* Generalised least squares.

** Instrumental variable technique for panel data developed by Hausman and Taylor.

a. Significant at the 0.05 level.

b. E1, E2 and E3 are dummy variables representing the education level of the household head. Illiteracy is the base level.

c. Fourth quarter is the base level for the season dummy variable.

and von Braun et al. (1989), for example, are that the present study uses total household income as the explanatory variable as opposed to household income per adult equivalent.

As noted below, the present study also includes additional explanatory variables such as the value of animals and land area, both of which could be interpreted as wealth variables yielding an income stream. Animal value and cropland area appear in the food consumption equation as a result of the joint production–consumption nature of the households in the study area. As such, they are also measures of household wealth and provide a stream of permanent income. Incomes on the other hand were measured quarterly and vary from season to season thus they are not a good indicator of permanent income. Cropland has a positive and significant influence on food consumption, with a corresponding elasticity of food consumption with respect to a land area of 0.26. Animal value positively and significantly influences food consumption: a marginal increase in animal value increases food consumption by 0.0034, with a corresponding elasticity of 0.183.

Controlling the household's total income and wealth, incomes handled by women have no significant positive impact on food consumption. The regression results suggest that an extra dollar given to either husband or wife will have the same effect on food consumption. The unitary model cannot be rejected on the basis of the food consumption equation, i.e. according to Table 10, men and women have the same preferences regarding food consumption.

Household size, in adult equivalent, controls for differences in family size across the sample. The negative and significant coefficient on this variable indicates that large households decrease the share of the budget allocated to food, i.e. larger households spend less per adult equivalent for each additional member. This may be due to (a) the food supply not increasing in proportion to family size, resulting in decreased food consumption per adult equivalent and (b) economies of scale effects, i.e. acquisition and preparation of food in bulk in the larger households permits savings.

The age and educational levels of the household head were included to measure the effects of knowledge and experience of household heads on food consumption decisions. Older and better-educated household heads are expected to be more efficient, i.e. may spend less on food. On the other hand, increased incomes from MODP technologies may lead to more food purchases. The estimates for education and experience of household heads suggest no significant effects on food consumption within their households.

Distances to the crop market and *woreda* identifiers were included to capture transaction costs that may vary across households. The estimates indicate that distance to the crop market had no significant effect on food consumption. The opportunity costs of time and money involved in travelling to the markets are low for the studied households. The coefficients of the quarterly dummy variables indicate significant seasonality in food consumption over the year. Food consumption is expected to be high during and after the harvesting season and low at other times of the year.

6.3.2 The effect of MODP technologies on calorie intake

The estimates in Table 11 pertain to the caloric intake equation (21). Again a test of equality of parameters for the CBC and LBC groups was examined first. The Wald statistic equation (23) for the equality of the caloric intake equation parameters (Table 11) was 77.53. The corresponding critical value for the χ^2_{14} at the 0.005 significance level is 31.32. It can thus be concluded that the specified determinants of calorie intake have significantly different effects for the two groups. To confirm that the difference is not solely in the intercept, the corresponding Wald statistic for equality of the slopes between the CBC and LBC groups was 45.99. The critical value for the χ^2_{13} at the 0.005 level is 29.82, implying that the slopes for the explanatory variables specified in the calorie intake equations were, indeed, significantly different for the CBC and LBC groups.

The role of MODP technologies on calorie intake was reflected most significantly by the value of animals reflecting wealth and a source of permanent income. The regression estimates (Table 11) for the determinants of calorie intake show a positive and significant effect of animal value on calorie intake in both the combined and CBC regressions. The estimated household calorie intake elasticities with respect to animal value were 0.16, 0.28 and 0.095 for the whole sample, the CBC and the LBC households, respectively.

Household size has a negative and significant effect on the calorie intake in all three cases. Again, this can be explained by (a) non-proportional increase in family size and calorie availability, and (b) economies of scale effects. The seasonal dummy variables are quite strong in all regressions. Nevertheless, there is no evidence of reduced seasonal effects between the LBC and the CBC households. Crossbred cow technologies do not mitigate calorie intake during the food deficit and food surplus periods. As confirmed in Figure 1, calorie stress is still high for the CBC households during the food deficit period (September–November). No other variables were significant in the calorie regressions.

6.3.3 The effect of MODP technologies on marketed surplus

The estimated results for the marketed surplus model presented in Table 12 relate to equation 22. A test for equality of the parameters for the CBC and the LBC was considered first. The Wald statistic (23) for the equality of the marketed surplus equation parameters between the CBC and the LBC groups was 28.61. Since the critical value for the χ^2_{15} at the 0.05 significance level is 25.00, the parameters for the marketed surplus equation explanatory variables are statistically different for the CBC and LBC groups. The specified determinants of the marketed surplus have different effects for the two groups. The Wald statistic (23) for equality of the slopes between the CBC and LBC groups and the critical values of 23.68 and 21.06 for the χ^2_{14} at the 0.05 and 0.10 levels, respectively, suggests only weak evidence that the slopes for the explanatory variables specified in the marketed surplus equations were different for the CBC and LBC groups.

Table 11. *Calorie intake equation.*

	All households		CBC households		LBC households	
Variables	GLS*	HT**	GLS	HT	GLS	HT
Constant	2443	2386.4	1997.53	1813.6	2329.02	2323.8
	(-324.7)	(-333.2)	(-408.705)	(-448.23)	(-312.23)	(-317.05)
Value of food consumed	-0.0983	0.3425	-0.2999	0.60355	-0.6032	(-0.5506)
	(-0.54)	(-0.5804)	(-0.6648)	(-0.8263)	(-0.8256)	-0.86411
Animal value	0.057	0.0547	0.0807	0.07869	0.0413	0.0409
	(0.0154)[a]	(0.0158)[a]	(0.01816)[a]	(0.0196)[a]	(0.0260)[a]	(0.0239)[b]
Cultivated land area	-100.68	-106.10	-256.86	-278.05	37.5605	37.605
	(-55.89)	(-57.279)	(52.7879)[a]	(57.762)[a]	(-62.28)	(-63.127)
Household size	-146.822	-139.19	-171.815	-157.34	-146.530	-146.02
	(26.972)[a]	(27.793)[a]	(26.1056)[a]	(28.924)[a]	(32.864)[a]	(33.376)[a]
Household head age	-5.7234	-5.6787	6.2113	6.878	-5.0238	-5.0238
	(-4.239)	(-4.3418)	(-4.8427)	(-5.2337)	(-4.288)	(-4.347)
E1 (1 = read and write 0 = otherwise)[c]	127.6	131.66	73.764	116.38	126.84	(126.09)
	(-135.4)	(-138.65)	(-156.568)	(-170.03)	(-149.63)	-151.69
E2 1 = elementary 0 = otherwise)[c]	96.57	94.633	435.667	470.85	-109.650	(-110.58)
	(-152.3)	(-155.94)	(188.386)[a]	(203.88)[a]	(-134.72)	-136.61
E3 (1 = High school 0 = otherwise)[c]	25.75	21.801	368.431	411.4	-80.249	-81.895
	(-186.5)	(-190.99)	(-234.781)	(-254.06)	(-172.21)	(-174.68)
Crop market distance	5.026	4.6426	25.829	26.644	-6.3079	-6.3904
	(-9.846)	(-10.085)	(10.343)[a]	(11.165)[a]	-10.175	-10.319
Location	329.7	336.15	335.445	347.4	263.135	263.72
	(138.915)[a]	(142.30)[a]	(147.233)[a]	(-158.95)	(-130.73)	(-132.53)
First quarter dummy[d]	362.5	345.99	376.216	337.29	374.123	372.43
	(56.094)[a]	(56.362)[a]	(88.646)[a]	(89.867)[a]	(71.825)[a]	(71.352)[a]
Second quarter dummy	640.3	623.68	753.014	705.12	557.057	555.83
	(56.128)[a]	(56.402)[a]	(90.9934)[a]	(93.422)[a]	(69.438)[a]	(68.715)[a]
Third quarter dummy	380.9	358.91	511.337	460.52	292.022	289.72
	(58.817)[a]	(59.484)[a]	(91.8468)[a]	(94.704)[a]	(75.862)[a]	(75.789)[a]
	N = 56	N = 56	N = 27	N = 27	N = 29	N = 29
	T = 4	T = 4	T = 4	T = 4	T = 4	T = 4
Calorie intake elasticity with respect to animal value		0.16		0.28		0.095

Notes: The dependent variable is household calorie intake/adult equivalent per day.
Figures in parentheses are standard errors.
* Generalised least squares.
** Instrumental variable technique for panel data developed by Hausman and Taylor.
a. Significant at the 0.05 level.
b. Significant at the 0.1 level.
c. E1, E2 and E3 are dummy variables representing the education level of the household head. Illiteracy is the base level.
d. Fourth quarter is the base level for the season dummy variable.

The elasticity of the marketed surplus with respect to the household income was positive. Evaluated at the sample mean, a 10% increase in income increased marketed surplus foods by 6, 5 and 9%, for the whole sample, CBC and LBC groups, respectively.

Table 12. *Marketed surplus equation.*

Variables	All households GLS*	All households HT**	CBC households GLS	CBC households HT	LBC households GLS	LBC households HT
Constant	457.408	453.85	1182.25	1184.1	179.031	161.85
	(-219.173)	(-224.89)	(-484.128)	(-506.65)	(-248.58)	(-201.47)
Household income	0.4006	0.379	0.36225	0.33	0.4689	0.4608
	(0.0459)[a]	(0.0529)[a]	(0.0609)[a]	(0.06889)[a]	(0.0765)[a]	(0.0989)[a]
Animal value	0.04508	0.04598	0.04736	0.04735	0.0083	0.00275
	(0.0106)[a]	(0.0110)[a]	(0.02163)[a]	(0.02273)[a]	(-0.0233)	(-0.01968)
Cultivated land area	9.2461	10.893	10.1887	-3.3871	11.9653	23.868
	(-38.3901)	(-39.468)	(-61.635)	(-64.981)	(-55.896)	(-46.575)
Household size	-23.9284	-22.923	-20.806	-17.803	7.3141	3.9697
	(-17.221)	(-17.724)	(-29.116)	(-30.674)	(-27.194)	(-22.221)
Household head age	-6.0615	-6.1035	-12.967	-13.056	-4.5978	-4.4310
	(2.8564)[a]	(2.9353)[a]	(-5.9149)	(-6.2052)	(-3.4949)	(-2.76)
E1 (1 = read and write 0 = otherwise)[b]	39.469	38.222	-121.324	-137.99	-9.1394	-9.7833
	(-91.4171)	(-93.939)	(-186.177)	(-196.08)	(-122.01)	(-97.221)
E2 (1 = elementary 0 = otherwise)[b]	36.9598	40.242	-92.023	-99.428	7.2792	4.9623
	(-102.852)	(-105.74)	(-226.398)	(-237.74)	(-111.74)	(-90.0749)
E3 (1 = high school 0 = otherwise)[b]	-79.1653	-77.609	-460.409	-470.12	-27.763	-36.493
	(-125.617)	(-129.08)	(-282.523)	(-296.67)	(-140.02)	(-111.41)
Crop market distance	-19.0719	-18.731	-44.4039	-44.3664	-2.7516	-1.2518
	(6.8587[a])	(7.0550)[a]	(12.726)[a]	(13.348)[a]	(-8.8256)	(-7.4396)
Wife's income	0.2404	0.251	0.2841	0.29851	0.1054	0.18026
	(0.0857)[a]	(0.0881)[a]	(-0.1143)	(0.1175)[a]	(-0.1553)	(-0.1619)
Location	26.0464	21.95	247.78	240.58	-65.536	-73.526
	(-94.3417)	(-97.046)	(-176.824)	(-185.87)	(-107.36)	(-85.8)
First quarter dummy[c]	101.415	109.35	59.886	71.223	137.166	132.15
	(-69.4575)	(-69.399)	(-109.42)	(-107.89)	(-75.194)	(-92.363)
Second quarter dummy	73.7331	82.315	181.675	201.5	-9.0482	-12.726
	(-69.6006)	(-69.679)	(-113.818)	(-113.56)	(-71.035)	(-87.105)
Third quarter dummy	-30.5158	-25.975	74.11	81.689	-126.312	-128.59
	(-67.872)	(-67.381)	(-108.214)	(-106.35)	(-70.749)	(-86.904)
	N = 56	N = 56	N = 27	N = 27	N = 29	N = 29
	T = 4	T = 4	T = 4	T = 4	T = 4	T = 4
Marketed surplus elasticity with respect to income		0.6		0.458		0.888

Notes: The dependent variable is value of food marketed surplus.
Figures in parentheses are standard errors.
* Generalised least squares.
** Instrumental variable technique for panel data developed by Hausman and Taylor.
a. Significant at the 0.05 level.
b. E1, E2 and E3 are dummy variables representing the education level of the household head. Illiteracy is the base level.
c. Fourth quarter is the base level for the season dummy variable.

Both income in the hands of women and animal value had positive and significant effects on marketed surplus for the combined sample and CBC group.

Distance to the crop market was negatively and statistically significant for the combined sample and for the CBC group. Households far away from the marke: find it difficult to engage in commercial activities. This has negε tive implications for uti isation of MODP technologies and consequently food production and food security. Neither the cropland nor the demographic variables had statistically significant effects on the marketed surplus.

6.3.4 The overall effects of MODP technologies

The food consumption, calorie intake and marketed surplus equation regression results presented in Tables 10, 11 and 12 show positive and significant effects of MODP technologies on food security and food production. These effects are reflected mainly through the effects of incomes and wealth (measured by animal value and land area).

The calorie intake and marketed surplus regression results show strong linkages between MODP technologies, calorie intake and food marketed surpluses. The Wald tests for the equality of the parameters and the slopes between the CBC and the LBC groups depicted that the specified determinants of calorie intake and marketed surpluses have significantly different effects for the two groups, with the two groups having different slopes. The CBC group consumes on average 30% more calories/adult equivalent per day. The quarterly average value of surplus food marketed by the CBC group is 82% higher than that of the LBC group (Table 13). The relevant question is how much of the increases are due to differences in the characteristics of the CBC and LBC households, such as the more valuable cattle, and how much is due to the differences in responses by the two groups, i.e. the $\hat{\beta}$s. The Oaxaca (1973) procedure is an approach to separate the two components:

$$\bar{y}_1 - \bar{y}_2 = (\bar{x}_1 - \bar{x}_2)\hat{\beta}_1 + (\hat{\beta}_1 - \hat{\beta}_2)\bar{x}_2 \tag{24}$$

where $\bar{y}_1$ and $\bar{y}_2$ represent the average daily adult equivalent calorie intake for the CBC and LBC groups, respectively, in the case of calorie intake and the average quarterly value of surplus food marketed by the two groups, in the case of marketed surpluses. The variables $\bar{x}_1$ and $\bar{x}_2$ are the vectors of the mean values of the regressors for the CBC and LBC groups, respectively. The estimated parameter vectors, $\hat{\beta}_1$ and $\hat{\beta}_2$ for the CBC and LBC groups, respectively, are in turn for the calorie intake and the marketed surplus equations. The first term on the right hand side of (24), $(\bar{x}_1 - \bar{x}_2)'\hat{\beta}_1$ represents the estimated effects due to group differences in the household characteristics and the second term, $(\hat{\beta}_1 - \hat{\beta}_2)'\bar{x}_2$, represents the estimated effects due to response differences for the two groups.

Based on the above partitioning, 63% of the difference in calorie intake between the CBC and LBC households can be attributed to differences in household characteristics, while the estimated parameter differences account for only 37% of the difference (Table 13). Interestingly, the estimated 321 calorie increase, resulting from the CBC household

Table 13. *Sources of calorie intake and marketed surplus differentials between the CBC and LBC groups.*

					Oaxaca decompositions due to group differences			
			$(\bar{Y}_{CBC} - \bar{Y}_{LBC})$		Means of variable $(\bar{X}_{CBC} - \bar{X}_{LBC})'\beta_{CBC}$		Estimated parameters $(\beta_{CBC} - \beta_{LBC})'\bar{X}_{LBC}$	
Equations	$(\bar{Y}_{CBC})$	$(\bar{Y}_{LBC})$	Units	Percentage difference	Units	Percentage difference	Units	Percentage difference
Calorie intake	2194	1686	508	30	321 (-85)	63	186 (-104)	37
Marketed surplus	852	468	384	82	290 (99)	76	94 (-113)	24

Note: Figures in parentheses are standard errors.

characteristics relative to the LBC households, is statistically significant given the estimated standard error of 85, while the portion due to the different parameter estimates is not (186 with an estimated standard error of 104).

Seventy-six per cent of the difference in value of marketed surplus food between the CBC and the LBC groups is accounted for by the difference in household characteristics, while only 24% of the difference can be attributed to the estimated parameters (Table 13).

Attributing the differences in income and animal values between the CBC and LBC groups to the MODP technologies provides a basis for evaluating the benefits of the technology in terms of increased food consumption, calorie intake and marketed surplus. The EB 240.7 difference in income resulted in an estimated EB 8.2 increase in food consumption, amounting to 7.8% of food consumption of the average LBC household (Table 14). The ownership of the crossbred cattle dramatically increased the value of animals for the CBC households by EB 3925.6, resulting in an estimated EB 15.1 (14.4%) increase in food consumption relative to the LBC households. The large increase in the value of the animals correspondingly resulted in an estimated increase of 214.8 calories per day (12.7%) in the CBC households.

Table 14. *Predicted changes in food security and food marketed surplus resulting from MODP technologies.*

							Predicted change independent variable	
Equations and variables	$\bar{Y}_{CBC}$	$\bar{Y}_{LBC}$	$(\bar{Y}_{CBC} - \bar{Y}_{LBC})$	$\bar{X}_{CBC}$	$\bar{X}_{LBC}$	$(\bar{X}_{CBC} - \bar{X}_{LBC})$	$(\bar{X}_{CBC} - \bar{X}_{LBC})'\hat{\beta}$ combined	% change
Value of food consumed	1340	105	34					
Income				1155	914	241	8.2	7.8
Animal value				7828	3903	3926	15.1	14.4
Calories[a]	2194	1686	508					
Animal value				7828	3903	3926	214.8	12.7
Marketed surplus	852	468	384					
Income				1155	914	241	91.2	19.5
Animal value				7828	3903	3926	180.5	38.6

a. Value of food consumed is not included since the parameter estimate is not significantly different from zero.

Improvements in the marketed surplus benefit not only the farm household, but also the non-farm population by increasing the domestic supply of food. The EB 240.7 increase in income resulted in an estimated EB 91.2 (19.5%) increase in marketed surplus relative to the LBC households. The programme induced increase in animal value resulted in roughly twice as large an increase in marketed surplus: EB 180.5 (38.6%).

7 Conclusions and implications for policy and future research

7.1 Conclusions

Market-oriented dairy production technologies had positive and significant impacts on food security and food production in the study area. The estimated models show a strong linkage between higher incomes (current and permanent as measured by animal value), resulting from the introduction of MODP technologies, and food consumption, calorie intake and marketed surplus.

The effects of changes in income and animal value resulting from the MODP technologies and their impacts on food security and food production differences between the CBC and LBC groups show these two variables resulted in 7.8 and 14.4% increases in food consumption and 19.5 and 38.6% increases in marketed food surpluses, respectively. The increased animal value from the introduction of the MODP technologies accounted for a 12.7% increase in calorie intake. Households that used MODP technologies increased their incomes and animal values significantly, relative to households using traditional dairy production methods. The increased resources led to significantly higher food consumption, calorie intake and marketed surplus.

Households with crossbred cows consumed on average 30% more calories per adult equivalent than households with local cattle. This is consistent with the greater profits possible from dairying with crossbred cows. Increases in food consumption and calorie intake realised by respondent CBC households, confirm the widely held view of proponents (for example the World Bank) of commercialisation of small-scale farms, that food security will improve with the raise in income that accompany the development process. The calorie intake patterns of the CBC and LBC households were similar and suggested that intensified dairying improved but did not significantly mitigate seasonal calorie intake in CBC households.

Studies in other areas have indicated that as 'cash crops' were introduced in smallholder production systems and there was greater market integration, women would lose control over cash incomes to men who tend to spend less on food for the household. A concern, expressed in the literature, has been that with commercialisation of dairying, men may take over the marketing of milk from women. If women lose possession of the milk income, food consumption could decline since they typically spend the income on food and household essentials. In contrast to the findings of other studies, commercialisation of dairy production in the Ethiopian highlands made both men and women better off in terms of increased income. The dairy income of women increased, although in relative terms while men's income increased much more. The results of this study showed that women in households using improved crossbred cows maintained possession of the income allocated to food purchases and continue to purchase more than 70% of the food eaten at home. Women's abilities to fulfil traditionally defined tasks (such as food purchases and sale of dairy products, according to gender division of labour) were enhanced by the introduction of market-oriented dairying in the study area.

Although intensified dairying showed the potential for significant contribution towards improving food security, the prevalence of food insecurity in Ethiopia remains high. The findings that the CBC were meeting 94% and the LBC households only 72% of the recommended minimum daily calories per capita, confirmed the significance of the problem and continued needs. This study, therefore, contributes to the economic development literature, particularly concerning food security, agricultural commercialisation and women in development, through a better understanding of the roles of improved dairying and commercialisation of smallholder agriculture in enhancing food production and food security. It also provides an empirical examination of the unitary and collective models. The preceding analysis suggests the following:

- Dairying with crossbred cows improves, but does not mitigate consumption. Earlier findings (Bouis and Haddad 1990; Kumar 1994) came to the same conclusion that commercialisation of small-scale farmers improved food security. The above studies did not address the issue of income smoothing.
- Commercialisation of dairy production in the Ethiopian highlands makes both men and women better off in terms of increased income, but men more so than women. Intensified dairying increased income in the hands of women and enhanced their ability to purchase more food, a task traditionally ascribed to women by the gender division of labour. This contrasted with findings from other areas (e.g. Thomas-Slayter and Bhatt 1994) which suggested that with commercialisation of dairying, women may lose 'control' over cash incomes to men who tend to spend less on food for the household.
- On the basis of women's income levels, the regression analysis results did not lead to a rejection of the unitary model. This is in contrast to findings by Quisumbing and Maluccio (1999) who suggest weak gender preferences in Ethiopia, i.e. individuals within the households have some differences in preferences.

This study applied an innovative and multifaceted approach, which used consistent instrumental variable panel data analysis techniques in assessing food security and food production consequences in the context of livestock production. Previous studies of the food security effects of commercialisation of smallholder agricultural production, traditionally modelled the food consumption and calorie intake equation as a system of recursive equations in the context of cash crop production only. When variables on one side of the equation are simultaneously determined with the variables on the other, either traditional instrumental variable techniques using instruments from outside the model or 'within' panel data estimators are normally used. Although the 'within' estimator for panel data purges the correlation problem from the model, it does not permit estimation of the parameters of the time-invariant variables. This study used instrumental variable techniques developed for panel data by Hausman and Taylor (1981) and used instruments from within the models that permitted consistent estimation of all parameters in the presence of correlation between household effects and a subset of the explanatory variables.

Another contribution of the study is the application of the Oaxaca (1973) procedure to separate the sources of differences in calorie intake and food marketed surplus between values of the explanatory variables and the response differences for the CBC and LBC households.

7.2 Policy implications

The findings of this study suggest that agricultural growth fostered by technological change and commercialisation of peri-urban small-scale farmers is a powerful contributor to the improvement of food security. With the strong positive relationship established between food security improvements and increased income and wealth, the research has illustrated an improved livestock technology, where economic welfare is improved via agricultural development.

The results of the study indicate that incomes in the hands of women did not have additional beneficial effects on the household food consumption beyond the total household income. The finding suggests that men and women in the Ethiopian highlands have common preferences in household food consumption. Based on the results of this study, policies that increase household incomes, without regard to gender, will have the same effects on food consumption as those that target individuals by gender.

The new initiative increased the income of men and women, though men more so than women. Men used the increased income for investment in farm operations, such as for the purchase of fertiliser, herbicides, animal feed and the provision of animal services. The consequence was increased food production.

Farmers using MODP technologies received several sources of financial and technical support from the research project. This included subsidised prices of crossbred cows, animal medicines and veterinary services, advice on forage production, breeding practices, management of animals, milk and dairy products. An interesting question is whether the MODP system will be viable when the programme ends? Will the animals and services be available in the open market and will farmers be able to purchase them without subsidies? Wide adoption of the MODP technologies in the Ethiopian highlands will require a level of profitability for the farmers to finance the purchase of the crossbred cattle. The adoption of the new initiative can be facilitated with the development of the necessary infrastructure and institutions, such as dairy input and output markets, transportation, veterinary and improved livestock extension services etc.

Animal feed scarcity, diseases and poor genetic makeup of cattle and poor extension services result in depressed milk production. This situation encourages the importation of milk and dairy products to meet the local demand, despite the fact that Ethiopia is the first country in Africa and the tenth in the world in livestock production (Belachew et al. 1994). Facilitating and strengthening services such as artificial insemination and other veterinary services, credit and provision of upgraded cattle to peri-urban small-scale farmers are all essential to increase milk production.

The incentives for better production of dairy products are likely to improve with the liberalisation of the dairy market. These incentives are eroded by a state dairy product marketing monopoly, the Dairy Development Enterprise (DDE) that virtually eliminates seasonal milk price fluctuation in contrast to the wide price fluctuations of other commodities in the region. Public and private investment in infrastructure improvements that facilitate technological change, such as roads, collection points and chilling centres, are likely to be important in a liberalised market environment for farmers to increase their productivity.

The income opportunities in dairying for smallholders make a strong case for further policy attention to market-oriented dairying. Improving the effectiveness of livestock services, freeing imports of animal medicines and feed markets from constraining regulations and enabling functioning dairy co-operatives may be central to these efforts. Encouraging market-oriented dairy production will require producer price incentives coupled with the market outlets in outlying areas. The DDE that targets domestic urban sales has not demonstrated the potential for expansion or the ability to support higher producer prices, especially if compelled to operate without subsidy (Staal and Shapiro 1996). One feasible option for market-oriented dairying expansion could lie in the informal collection and processing of milk operated by, say, small dairy co-operatives. This could overcome transport constraints for the marketing of milk. Such dairy co-operatives may go on to provide other services, such as credit to members, strengthening the institution and contributing to dairy development and may also give producers a voice in policy-making. Other constraints to the successful expansion of commercial dairying in more rural areas lie in livestock services and scarcity of feeder roads.

7.3 Limitations of the study and suggestions for future research

The research focused on evaluating the effects of new technology on food security, food marketed surplus and on identifying policy implications for dairying with crossbred cows within the framework of the household model. The shortcomings of this study noted below suggest areas for future research.

The best way to achieve the objective of identifying the key factors that drive food security and marketed surplus outcomes, in the process of commercialisation of smallholder agriculture, would have been to collect data from the same households both before and after the technology was introduced. Such an approach could not be applied within this study. The second best option was used: a comparison of households with and without crossbred cows, but having the same resource endowment.

Data on calorie intake at the household rather than the individual level were used. Separation of household consumption by age and gender would have been appropriate for intra-household analysis, particularly for studies that target vulnerable members within the household, such as children under five, or pregnant and lactating women who require unique nutritional needs. In the Ethiopian highlands, the normal practice is for household members to eat from a common plate, thus precluding the collection of data at the individual level. Evaluating the calorie intake effect at the household level assumes equitable distribution of calories within the households. This may not be the case in low-income calorie deficient households. Calorie stress during heavy farming activity periods may result in household farm workers consuming more food than children.

The data set used in this study pertains to a relatively small number of households. Although statistically significant effects were found, inferences from a large data set would be valuable. In addition, the households were part of an experiment and not a random sample of the population using the technology in the absence of a concerted effort by various institutions to evaluate or monitor its viability. Nevertheless, the households are believed to be representative of the Ethiopian highland households.

As confirmed in this study, the introduction of new technologies and commercialisation of smallholder farming systems can directly affect food security. Identifying effective agricultural development policies can strengthen the positive effects of this process.

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